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SOME EFFECTS OF TEMPERATURE AND DAY-LENGTH ON THE BREAKING OF WINTER DORMANCY IN BLACK CURRANT

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In the course of an investigation on the effect of environmental factors on the growth and development of the black currant it was found that day-length had a marked effect on the duration of extension growth and on the onset of dormancy (Hoyle, 1955). The experiments reported here were carried out to examine the inter-relations of day-length and winter chilling on the breaking of winter dormancy.

Material and methods.

Young plants of the variety Boskoop Giant were grown in John Innes potting compost No. 2 in 10 in. pots. Two methods of winter chilling were used. The plants were either given natural cold treatment out of doors and brought into the heated glasshouse at intervals, or placed in a cold room at 38° F. ±2° (3·3° C. ±1·1°) with low intensity illumination for 8 hours per day for the appropriate period and then transferred to the glasshouse.

In Experiments 1 and 2 the glasshouse was maintained at a minimum night temperature of 50° F. (10° C.). The plants were divided into two batches, one receiving short days (S.D.) from 8 a.m. to 4 p.m. and the other long-day treatment (L.D.), viz., daylight from 8 a.m. to 4 p.m. supplemented with low intensity light, as described previously (Hoyle, 1955), to give a 17-hour day. The plants had been pruned at potting to give at least one shoot cut hard back to 3–4 buds and one entire shoot per plant. Records were made of the effects of chilling and day-length on the breaking of lateral buds on cut-back shoots, and of terminal and lateral buds on entire shoots. In Experiment 3 certain elaborations not present in 1 and 2 were introduced ; the particulars of these will be given later.

Owing to problems of space both for chilling and in the glasshouse, the number of replicates per treatment was necessarily limited, being 2, 3 and 4 in Experiments 1, 2 and 3 respectively. Likewise day-length and temperature treatments subsequent to chilling could not be duplicated and the data have not, therefore, been analysed statistically. The treatment effects are in the main, however, so large and consistent as to make it seem most unlikely that they could be due to positional effects in the glasshouse, or for instance to the difference in light intensity between the glasshouse and outside in Experiment 3 (see below).

Experiment 1.

Natural chilling was used in this experiment and the first batch of potted plants was brought into either L.D. or S.D. in the glasshouse from out of doors on 25th November 1955, and subsequent batches at fortnightly intervals thereafter until

17th February 1956. The mean weekly maximum and minimum screen temperatures at a meteorological station immediately adjacent to the experimental plants left outside for chilling are shown in Fig. 1.

Table I gives the mean number of days to bud-break, taken as the first appearance of the tip of a green leaf through the already swollen scale leaves. The mean number of days to bud-break is calculated both from the start of treatment in the glasshouse and from the beginning of the experiment (figures in brackets).

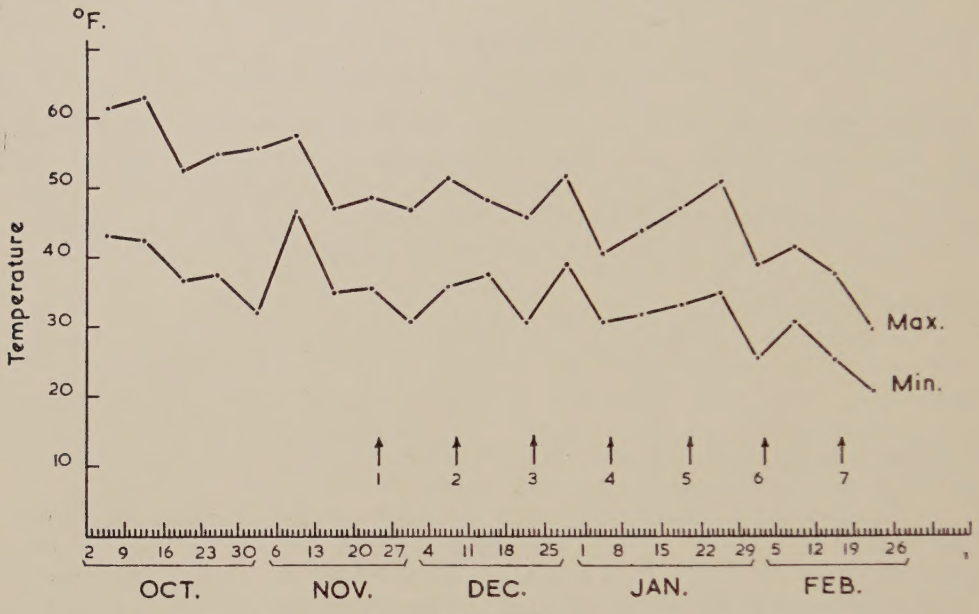

Fig. 1.

Mean weekly maximum and minimum screen temperatures out of doors, Experiment 1 ; arrows indicate dates when batches were transferred to glasshouse.

The plants brought in on 25th November showed no bud-break for many weeks. Those in L.D. did eventually break (Table I, line 1) but the lateral and terminal buds on the entire shoots in S.D. showed no bud-break during the four months of the experiment. A few plants were retained and a little spasmodic bud-break did eventually occur, but only after more than six months. With increasing amounts of natural cold weather the time to bud-break, calculated from the beginning of treatment in the glasshouse, became progressively less, so that the longest cold treatment produced bud-break in less than two weeks after transfer to L.D.

For comparable periods of chilling, plants maintained in L.D. broke more quickly after transfer to the glasshouse than those maintained in S.D., the time lag in S.D. being more pronounced the less the initial chilling. This was true for all three types of buds.

There was virtually no difference between terminal and lateral buds on entire shoots within day-length chilling treatments. Buds on cut-back shoots, however, broke more quickly than comparable terminal and lateral buds on entire shoots, particularly with S.D. and inadequate chilling.

TABLE 1.

Exp. 1. Effects of length of natural chilling period, of day-length and cutting back, on days to bud-break in Boskoop Giant; terminal buds, lateral buds and buds on cut-back shoots recorded separately. Figures outside brackets from start of treatment in glass-house, figures in brackets from start of experiment on 25th November.

Date brought in	Weeks additional cold	8-hour day			17-hour day		
		Cut-back shoots	Entire shoots		Cut-back shoots	Entire shoots	
			Terminal buds	Lateral buds		Terminal buds	Lateral buds
25.11.55	0	102 (102)	—	—	68 (68)	75 (75)	75 (75)
9.12.55	2	72 (86)	97* (111*)	88* (102*)	54 (68)	61 (75)	61 (75)
23.12.55	4	58 (86)	61 (89)	61 (89)	40 (68)	47 (75)	47 (75)
6. 1.56	6	44 (86)	47 (89)	47 (89)	33 (75)	33 (75)	33 (75)
20. 1.56	8	30 (86)	37 (93)	37 (93)	23 (79)	26 (82)	26 (82)
3. 2.56	10	19 (89)	26 (96)	26 (96)	16 (86)	19 (89)	16 (86)
17. 2.56	12	12 (96)	19 (103)	19 (103)	12 (96)	12 (96)	12 (96)

* Based only on those plants which did break and therefore underestimated.

When, however, the time to bud-break from the beginning of the experiment is considered, the results are somewhat different. In S.D. there was the same marked delay in bud-break in the two treatments receiving least chilling, but there was very little difference between treatments brought in subsequently, except for some further delay as the cold period was increased beyond 20th January. In L.D. there was no difference between the first four treatments; chilling beyond the beginning of January, however, tended to delay bud-break.

L.D. gave marked superiority over S.D. in the percentage number of lateral buds breaking for each chilling treatment (Table II).

TABLE II.

Exp. 1. Percentage of lateral buds breaking or in leaf by the 14th March.

Weeks additional cold from 25.11.55	Weeks in glasshouse	Photoperiod	
		8-hour	17-hour
0	16	0·0	31·2
2	14	5·5	44·5
4	12	9·6	45·3
6	10	19·1	49·0
8	8	22·5	70·5
10	6	30·7	66·4
12	4	52·5	80·2

EXPERIMENT 2.

Potted plants were transferred from out of doors to the cold room on 1st October 1956. At the same time the first batch was brought into the glasshouse for treatment in either L.D. or S.D. Further batches were transferred from the cold room at three-weekly intervals until 25th February. The mean maximum and minimum temperatures in the glasshouse during the period of the experiment are given in Table III. No appreciable variations in temperature occurred during the course of the experiment apart from some rise during the initial and final periods.

TABLE III.

Exp. 2. Mean maximum and minimum glasshouse temperatures.

Period	Mean temperature °F.	
	Minimum	Maximum
1st-22nd October	53·4	69·2
22nd October-12th November ..	50·2	59·5
12th November-3rd December ..	50·0	58·3
3rd-24th December	52·6	59·0
24th December-14th January ..	52·0	59·7
14th January-4th February ..	51·3	60·0
4th-25th February	51·2	61·5
25th February-18th March	53·8	66·3

TABLE IV.

Exp. 2. Effect of length of chilling period at 38° F., of day-length and cutting back, on days to bud-break in Boskoop Giant; terminal buds, lateral buds and buds on cut-back shoots recorded separately. Figures outside brackets from start of treatment in glasshouse, figures in brackets from start of experiment on 1st October.

Weeks cold treatment	8-hour day			17-hour day		
	Cut-back shoots	Entire shoots		Cut-back shoots	Entire shoots	
		Terminal buds	Lateral buds		Terminal buds	Lateral buds
0	—	—	—	107 (107)	89 (89)	105 (105)
3	—	—	—	47 (68)	82 (103)	79 (100)
6	—	—	—	45 (87)	75 (117)	56 (98)
9	98* (161*)	130* (193*)	107* (170*)	15 (78)	—	44 (107)
12	19 (103)	42 (126)	48 (132)	17 (101)	16 (100)	24 (108)
15	16 (121)	12 (117)	18 (123)	11 (116)	11 (116)	11 (116)
18	11 (137)	10 (136)	11 (137)	8 (134)	8 (134)	9 (135)
21	6 (153)	7 (154)	7 (154)	5 (152)	5 (152)	6 (153)

* Based only on those plants which did break, and therefore underestimated.

The results given in Tables IV and V show the same trends as in Tables I and II respectively. As in Experiment 1, increasing amounts of cold reduced the length of time to bud-break after transfer to the glasshouse. The final batch, which had received 21 weeks' cold treatment, broke within 7 days of being transferred to the glasshouse in both day-lengths.

As before, the plants in L.D. broke more quickly after transfer than those in S.D. and the difference between L.D. and S.D. lessened as the duration of chilling progressively increased. Thus plants in S.D. which had received 6 weeks or less at 38° F. showed no bud-break during the period of the experiment (27 weeks), whereas with 9 weeks' chilling bud-break in S.D. was irregular, only some plants showing bud-break during the experiment. With 12 weeks' chilling, bud-break in S.D. was fairly rapid in buds on cut-back shoots but took considerably longer for buds on entire shoots. In comparable L.D. plants the time to bud-break was much reduced.

When calculated from the start of the experiment on 1st October, however, the time to bud-break in S.D. decreased to a minimum after 15 weeks' chilling for both terminal and lateral buds (12 weeks for cut-back shoots). In L.D. there was little difference between those transferred to the glasshouse on 1st October and those transferred up to 12 weeks later. Chilling in excess of 12 weeks in L.D. and 15 weeks in S.D. tended to delay bud-break.

As before, buds on cut-back shoots in general broke more quickly than buds on entire shoots and the difference increased with decrease in chilling. With the longer chilling periods, however, there was less difference between buds on cut-back and entire shoots than in Experiment 1.

As in Experiment 1, long days gave a greater percentage number of lateral buds breaking than comparable short-day treatments (Table V).

TABLE V.

Exp. 2. Percentage of laterals breaking or in leaf by 8th April.

Weeks cold treatment from 1.10.56	Weeks in glasshouse	Photoperiod	
		8-hour	17-hour
0	27	0·0	33·1
3	24	0·0	24·2
6	21	0·0	31·1
9	18	5·4	33·2
12	15	26·1	32·5
15	12	37·8	44·7
18	9	50·6	42·9
21	6	55·3	71·8

EXPERIMENT 3.

Potted plants of the variety Boskoop Giant, all of which had been cut back to 3–4 buds per shoot, were placed in the cold room for 6 weeks on 13th October 1955. After removal from the cold room they remained out of doors for a further 4 days before further treatment. They were then divided into 10 groups of 4 plants each and given treatments consisting of the following combinations of day-length and temperature :

$$\left\{\begin{array}{l}8 \text{ hr.}\\ 13{\cdot}5 \text{ hr.}\\ 17 \text{ hr.}\end{array}\right\} \times \left\{\begin{array}{l}\text{Low temperature outside}\\ 50^\circ \text{ F. min. in glasshouse}\\ 60^\circ \text{ F. min. in glasshouse}\end{array}\right\}$$

The tenth batch were left outside for a further 8 weeks and then brought into the glasshouse with a minimum night temperature of 50° F. and natural day-length, at that time about 10 hours.

In order to obtain suitable low temperature treatment, plants were lighted outside the glasshouse in natural cold winter temperatures. The intermediate temperature was obtained by giving a minimum night temperature of 50° F. and controlling day temperatures by adequate ventilation to keep the temperature down as far as possible to 55° F. (12·8° C.). Only during the last few weeks of the experiment did the maximum temperature rise appreciably (Table VI). The high temperature groups were kept constantly above 60° F. (15·6° C.). Small differences in temperature between the lighting treatments occasionally occurred but these were exceedingly small compared with the much greater differences between the three temperature treatments.

TABLE VI.

Exp. 3. Mean maximum and minimum temperatures.

	Low temperature		50° F. minimum		60° F. minimum	
	Min.	Max.	Min.	Max.	Min.	Max.
December ..	35·0	47·0	50·6	55·6	—	—
January ..	31·6	43·4	51·0	56·3	62·5	73·3
February ..	29·0	42·0	48·7	54·9	61·4	71·8
March	35·3	51·8	52·8	66·6	62·2	71·0

TABLE VII.

Exp. 3. Effect of day-length, ambient temperature and chilling on bud-break in Boskoop Giant.

Weeks of chilling	Minimum temperature °F.	Day-length (hours)	Days to bud-break
6	Low. temp. (plants outside)	8 13·5 17	112*
6	50	8 13·5 17	— — 40
6	60	8 13·5 17	— 9 9
14	50	N.D.†	19

* Bud-break mid-March when ambient temperature favourable.
† Natural day-length about 10 hours when plants were transferred to glasshouse.

The results in Table VII show that high temperatures following 6 weeks low temperature pre-treatment were conducive to rapid bud-break*. Thus plants transferred to a minimum temperature of 60° F. and medium or long days showed bud-break after 9 days. This period was markedly increased in the medium and low temperature treatments.

The low temperature plants remained dormant under all day-lengths until mid-March when the ambient temperature became favourable and the plants then began to grow under all day-lengths (112 days from commencement of lighting).

The interaction of temperature and day-length was such that plants in the medium temperature showed bud-break only when grown under L.D. (in a time of the same order as for comparable buds on cut-back shoots in L.D. in Experiment 2) while those in the high temperature treatment showed rapid bud-break in both long and medium day-lengths. Plants grown in high temperature and S.D. showed some signs of bud-break but the buds never expanded fully and the odd leaf or two which did emerge gradually died off.

Plants which were given a total of 14 weeks chilling (6 in cold store and 8 out of doors) broke in 19 days with natural day-length (then about 10 hours) and a temperature of 50–55° F.

After the termination of the main experiment some transfer of plants to different conditions was made. Plants transferred from L.D. at 50° F. to S.D. at 50° F. or from L.D. at 60° F. to S.D. at 60° F. ceased growth and formed a terminal resting bud within 14 days of transfer. Plants transferred from 13·5 hours at 50° F. to 13·5 hours at 60° F. commenced growth within 14 days.

DISCUSSION.

The results in Experiments 1 and 2 show that both cold treatment and long days are effective in inducing bud-break in black currant.

The results in Experiment 2 suggest that in short days 15 weeks at 38° F. adequately fulfilled the chilling requirement of terminal and lateral buds of Boskoop Giant when the plants were subsequently maintained above 50° F. Cold treatment for longer than 15 weeks served only to increase the percentage bud-break and accelerated the rate of bud-break by a few days when calculated from the date of transfer to the glasshouse. When calculated from the start of the experiment on 1st October, cold for longer than 15 weeks in fact delayed bud-break. With inadequate chilling, bud-break was delayed or even prevented and the percentage bud-break was greatly reduced. Sergeev *et al.* (1957) working in Russia obtained a similar result and estimated the chilling requirement of black currant at 114 days when the mid-day temperature did not exceed 10° C. (50° F.).

In long days, on the other hand, there was no apparent effect of chilling. Bud-break, as calculated from the start of the experiment, was independent of whether the plants were chilled or not. Prolonged chilling tended to delay bud-break.

The interaction of day-length with chilling suggests that, when the latter was adequate, day-length was of secondary importance and bud-break occurred almost as readily in S.D. as in L.D. The percentage of lateral buds breaking was, however, almost always greater in L.D. than in S.D. for comparable periods of chilling. When,

* For criterion of bud-break, see Experiment 1, second paragraph.

however, chilling was inadequate the effect of day-length was marked and plants broke dormancy more rapidly in long days than in short. Long days provided an effective substitute for chilling. A similar effect of day-length in replacing chilling has been found for sugar maple (Olmsted, 1951). For many woody species, however, there appears to be considerable variation with regard to the effectiveness of day-length in the breaking of dormancy; and the interaction between photoperiodic effects and chilling requirement has not been investigated in detail (Wareing, 1956).

In the experiments reported here, cutting back of the shoots reduced the days to bud-break in those buds remaining, particularly in S.D. when chilling was inadequate. Injury is known to have " a distinct, but rarely strong dormancy-breaking effect " (Doorenbos, 1953), but the effect of the pruning wound does not seem to be a fully adequate explanation of the effect obtained here. Alternatively the removal of inhibitory substances in the portion of the shoot removed, or a reduction in competition between those buds remaining, might have contributed to the result. On entire shoots there was in general little difference between the responses of terminal and lateral buds.

The results in these experiments also show that the treatment of the plants subsequent to chilling had a marked influence on the rate of bud-break. Thus low ambient temperature may delay bud-break and even prevent it with insufficiently chilled plants in short days. High temperatures had an opposite and hastening effect. Similar results have been found with embryo-cultured peach seedlings from non-after-ripened seedlings, high temperatures alone even in short days sufficing to break dormancy (Lammerts, 1943).

Under natural conditions in this country, the chilling requirement of the buds is normally fulfilled some time before bud-break, the buds remaining in a state of imposed dormancy until the temperature becomes favourable. The low temperature series in Experiment 3 illustrate this point. In regions with a mild winter, where the chilling requirement of the buds is not entirely fulfilled, increased ambient temperature and/or lengthening day might be expected to assist in breaking dormancy.

SUMMARY.

The effects of different periods of chilling—given either as natural cold weather, or in a cold room at 38° F. (3·3° C.)—cutting back, and subsequent day-length and temperature treatment on bud-break in black currant, variety Boskoop Giant, have been investigated.

It was found that increasing amounts of cold treatment up to 15 weeks at 38° F. (3·3° C.) progressively decreased the length of time to bud-break in short days. With inadequate chilling and short days, bud-break was delayed or even prevented and the percentage bud-break was much reduced.

Plants broke dormancy more quickly in long than in short days when chilling was inadequate. Long days were shown to replace chilling.

The percentage number of lateral buds breaking was greater in long than in short days for each chilling treatment.

Buds on cut-back shoots in general broke more quickly than buds on entire shoots, the differences increasing with decrease in chilling.

In general, low temperature following the chilling period delayed bud-break and high temperature accelerated it. There was also an interaction with day-length.

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EFFECTS OF DIFFERENT SOIL MOISTURE CONDITIONS DURING THE SEEDLING STAGE ON THE GROWTH AND YIELD OF EARLY SUMMER CAULIFLOWERS

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THE effects of different soil moisture conditions during the seedling stage on growth and development of the cauliflower plant have been studied by few workers and the results obtained have been conflicting. In the United States, Aamlid (1952) and Carew and Thompson (1948) found that dry soil conditions during the seedling stage gave slight, but generally non-significant, increases in yield, whereas Robbins *et al.* (1931) found that dry soil conditions caused more plants to button*, with the result that a smaller number of plants yielded marketable curds. In this country, Parkinson (1952) showed that a 16-day period of drought during the seedling stage resulted in the production of slightly smaller curds. However, the object of Parkinson's work was to find means of shortening the time to seed formation required for breeding purposes rather than to determine a suitable soil moisture treatment to increase marketable yields.

The optimum soil moisture conditions for raising early summer cauliflower plants in this country have not been established experimentally, but in commerce the plants are kept very dry during the winter period. It is a common practice to sow the seed in late September, overwinter the plants under cold glass and plant in the field in early spring. Adequate ventilation and the sparing use of water are considered to be essential for the successful growing and wintering of the plants and it has been stated that " . . . no harm is caused even when plants are allowed to flag and turn blue for want of water during the winter months " (Ibbett and Twyman, 1953).

In a previous paper (Salter, 1959) the responses of early summer cauliflower plants to different soil moisture conditions in the field were described. This paper describes experiments to determine the response of this crop to different soil moisture conditions applied during the winter from October until planting-out time in March, and the interactions obtained with subsequent field treatments.

MATERIALS AND METHODS.

Experiments were carried out during the seasons 1956–57, 1957–58 and 1958–59. In the following account they are designated by the year in which the plants were harvested, i.e., the 1957 experiment refers to plants sown in the autumn of 1956 and harvested in the summer of 1957.

* A " buttoned " plant has been defined by Jensma (1957) as one having smaller leaves, a lower leaf number and a smaller curd than a normal plant.

The variety used in 1957 was Finney's 110 ; in 1958 and 1959 two varieties, Finney's 110 and Remme, were used.

Cultural details.

Seed was sown in late September and the seedlings were pricked out into 3 in. pots containing John Innes potting compost (No. 1) in early October. The plants were overwintered in unheated frames for the 1957 and 1958 experiments and in 1959 in a frame where, for other purposes, the temperature was not allowed to fall below 30° F. Adequate ventilation was given throughout the winter months and after planting in the field in March all plants were watered to establish them. The plants were then treated as for a normal commercial crop except for the field irrigation treatments.

Frame treatments.

These were applied from October until the plants were moved to the field in March and consisted of two treatments, wet and dry, as follows:

Frame wet treatment. Plants were watered daily in the 1957 experiment and three times per week in the 1958 and 1959 experiments, irrespective of prevailing weather conditions.

Frame dry treatment. The plants were allowed to deplete the soil in the pots almost to the wilting point before being watered. The frequency of watering was approximately once every fortnight.

No attempt was made to apply measured quantities of water, but sufficient was added at each watering to restore the soil in the pots to field capacity.

Field treatments.

These were maintained from one week after planting until harvest. Half of each batch of plants raised under wet or dry conditions in the frames was given one of the following treatments.

Field wet treatment. In 1957 plants were irrigated daily with a volume of water equal to the previous day's evapo-transpiration loss, calculated according to a modification of the method of Penman (1948). In 1958 and 1959, the plants were irrigated whenever the available water in the root zone had been depleted by 25%, sufficient water then being given to restore the soil to field capacity. The timing of irrigation in this treatment was determined from regular gravimetric determinations of the moisture content of soil samples taken to the maximum depth of rooting at each sampling date. This treatment followed from the results of previous experiments (Salter, 1959).

Field dry treatment. The plants received no water other than rainfall.

Experimental layout.

While the plants were overwintering in the frames, the different treatments were given to batches selected at random to overcome any positional effects in the frames.

In the field a split-plot layout was used. The main plots were used for the field treatments, with three replicates of each field treatment in 1957 and 1958 and four replicates in 1959. Frame treatments and varieties occupied the sub-plots with two

replicates of each combination in each main plot. The sub-plots each contained six or more plants.

An additional number of plants subjected to each of the treatments was also grown to provide material for post-planting growth measurements.

Plant growth measurements.

During growth. Random samples, each of six plants from each treatment, were taken at intervals from the cotyledon stage until planting time. The number of leaves and leaf primordia were counted after dissecting the growing points and the fresh and dry weights of the whole plants were determined.

At planting time random samples of twelve plants from each treatment were taken and, in addition to the above measurements, determinations were made of the percentage total nitrogen in the leaves of each plant and in the compost in which the plants were grown.

In 1957 and 1959, at suitable intervals after planting in the field, random samples of ten plants were selected from the spare plants of each treatment and the growing points were dissected to determine the onset of curd initiation. The date when 50% of the plants sampled had developed a wide apex, indicating the transition stage from a vegetative to a generative condition of the apex (Salter, 1960), was regarded as the time of curd initiation.

Shortly after planting in the field in 1957 and 1959, the 10th leaf formed after the cotyledons was marked by punching a small hole in the lamina. This was done before the lower leaf scars and cotyledon scars had become obscure. Subsequently the 15th and 20th leaves were similarly marked.

At harvest. The same person judged when each curd was ready for cutting and the curd size and quality were recorded for each plant. The curd and untrimmed leaves were weighed to give the untrimmed head weight. In addition, the total number of leaves formed before curd initiation was noted. This latter figure was determined by counting the number of leaves up to the last leaf which did not have a curd peduncle developed in its axil. The number of buttoned plants was also recorded.

EXPERIMENTAL RESULTS.

Behaviour of plants in frames.

The different soil moisture conditions imposed from October onwards affected the growth of the seedlings almost immediately. At each sampling date, plants subjected to the wet treatment had higher fresh and dry weights, and a greater number of leaves, than those given the dry treatment. At planting time in March the frequently watered plants were larger and lighter green in colour than the infrequently watered which were of a " harder " type of growth. Typical examples from each treatment photographed at planting time (1959) are shown in Fig. 1.

In 1957 and 1959, analyses were made of plant and compost material at planting time and the results obtained in 1957 are shown in Table I. The plants at this stage were not so large in 1959 as in 1957, with mean fresh weights (Finney's 110) of 5·77 and 4·75 gm. for the wet and dry treatments respectively, and mean leaf numbers of 18·3 and 17·9, but the trends of the results for both varieties were the same as in 1957. In both years the wet treatment had caused a significant reduction in the

percentage dry matter of the leaf and a significant reduction in the nitrogen percentage in the dried leaves. It is possible that an intermediate water regime combining maximum nitrogen content with optimum leaf production might give better plant growth.

TABLE I.

Effect of soil moisture treatments on growth and composition of plants overwintered in frames. Measurements made at planting time, 13th March 1957; var. Finney's 110.

	Frame treatment		L.S.D. P=0·05
	Wet	Dry	
Fresh weight of shoot (gm.)	14·7	11·7	2·69
Number of leaves initiated	26·0	23·3	4·06
% dry weight of leaf lamina	16·0	19·3	1·37
% total nitrogen in dried leaf lamina ..	2·32	2·77	0·24
% total nitrogen in air-dry compost ..	0·25	0·23	0·03

BEHAVIOUR OF PLANTS IN THE FIELD.

Harvest measurements for the three experiments and the statistical significance of the results are presented in Tables II, III, IV, V and VI and are summarized in Table VII. There were no significant interactions between frame and field treatments as reflected in harvest measurements. With the exception of a significant interaction between variety and frame treatment in 1958, as a result of the lack of response of the variety Remme to the frame wet treatment, there were no significant interactions between variety and frame or field treatments as measured by untrimmed head weight, curd size, earliness or leaf number. All results, therefore, have been presented in the form of main effects of frame and field treatments, except in Table VI.

Effects of frame treatments.

The mean untrimmed head weight of variety Finney's 110 was increased by wet conditions in the frame in all years (Table II). The same result was obtained with variety Remme in 1959, but not in 1958.

TABLE II.

Mean untrimmed head weight (gm.) at harvest.

Variety	Year	Main effect of frame treatments			Main effect of field treatments		
		Wet	Dry	L.S.D. P=0·05	Wet	Dry	L.S.D. P=0·05
Finney's 110	1957	870	717	161	953	634	264
	1958	1512	1330	105	1550	1292	263
	1959	1518	1321	70	1730	1109	309
Remme ..	1958	1347	1392	105	1431	1308	263
	1959	1468	1310	70	1657	1121	309

The response to the treatments as measured in terms of mean curd size is shown in Table III.

TABLE III.

Mean curd diameter (in.) at harvest.

Variety	Year	Main effect of frame treatments			Main effect of field treatments		
		Wet	Dry	L.S.D. P=0·05	Wet	Dry	L.S.D. P=0·05
Finney's 110	1957	4·7	4·0	0·36	4·6	4·1	0·75
	1958	5·2	5·2	0·16	5·2	5·2	0·22
	1959	5·1	4·3	0·12	5·0	4·4	0·29
Remme ..	1958	5·0	5·1	0·16	5·1	5·0	0·22
	1959	5·1	4·3	0·12	5·0	4·4	0·29

Plants of the variety Finney's 110 showed a significant positive response to the wet treatment in two out of the three experiments ; plants of the variety Remme responded similarly in 1959 but not in 1958.

The frame treatment influenced the date of harvesting of the plants (Table IV), the wet treatment causing the mean harvest date to be later in all years and for both varieties than that for plants subjected to the dry treatment.

TABLE IV.

Earliness: mean number of days after 1st May when harvested.

Variety	Year	Main effect of frame treatments			Main effect of field treatments		
		Wet	Dry	L.S.D. P=0·05	Wet	Dry	L.S.D. P=0·05
Finney's 110	1957	25·7	21·5	4·9	25·0	22·2	6·8
	1958	53·5	46·3	1·4	49·9	49·9	2·2
	1959	40·4	37·0	1·0	39·1	38·3	1·6
Remme ..	1958	54·0	53·1	1·4	53·3	53·8	2·2
	1959	40·2	37·1	1·0	38·2	39·1	1·6

The time of curd initiation in 1957 was affected by soil moisture conditions experienced during the seedling stage. Plants given the frame wet treatment had initiated curds by the 8th March and plants from the frame dry treatment on the 18th March. In 1959 there was a smaller, though not significant, difference between the time of curd initiation of plants from the wet and dry treatments, which initiated curds by the 10th and 13th April respectively.

Soil moisture conditions in the seedling stage influenced also the number of leaves formed prior to curd initiation (Table V). With both varieties the wet treatment caused a larger total number of leaves to be formed per plant than the dry treatment.

TABLE V.

Mean number of leaves formed before curd initiation.

Variety	Year	Main effect of frame treatments			Main effect of field treatments		
		Wet	Dry	L.S.D. P=0·05	Wet	Dry	L.S.D. P=0·05
Finney's 110	1957	27·8	27·0	1·10	27·5	27·3	1·44
	1959	29·4	28·1	0·36	28·7	28·8	0·49
Remme ..	1959	29·3	28·3	0·36	28·9	28·7	0·49

Effects of field treatments.

The frequency of irrigation necessary to maintain the field wet treatment, and the maximum deficit which developed in the unwatered (dry) plots, depended on the prevailing weather conditions, particularly the incidence of rainfall, and naturally varied from year to year. In 1957, 9·00 in. of water was applied to the wet plots during the period from planting to harvesting, 2·83 in. of rain fell during the period and the maximum deficit which developed under the dry treatment was 2·94 in. at the end of harvest. The corresponding figures for 1958 were 3·75, 5·26 and 1·15, and for 1959, 3·87, 4·01 and 3·07. Plants given the wet treatment benefited from irrigation during 1957 and 1959 and produced a higher untrimmed head weight (Table II) and a larger curd (Table III) when compared with unwatered plants. In 1958, however, the rain prevented the occurrence of a large deficit in the dry treatment and as a result the wet and dry treatments were not sufficiently different to produce significant differences in growth at harvest.

The time of cutting and the mean leaf number per plant were not significantly affected by the field treatments in any of the experiments (Tables IV and V).

The numbers of plants which buttoned in 1957 are shown in Table VI. One third of the plants subjected to the dry treatment in the frame and not irrigated in the field, produced buttons.

No buttoned plants were produced under any treatment in 1958 and 1959.

TABLE VI.

Number of plants which buttoned in 1957 (out of 60 in each treatment).

Field treatments	Frame treatments		Field treatment totals
	Wet	Dry	
Wet	7	11	18
Dry	7	20	27
Frame treatment totals	14	31	

L.S.D. for comparisons within the body of the table =9·1.

PLATE I

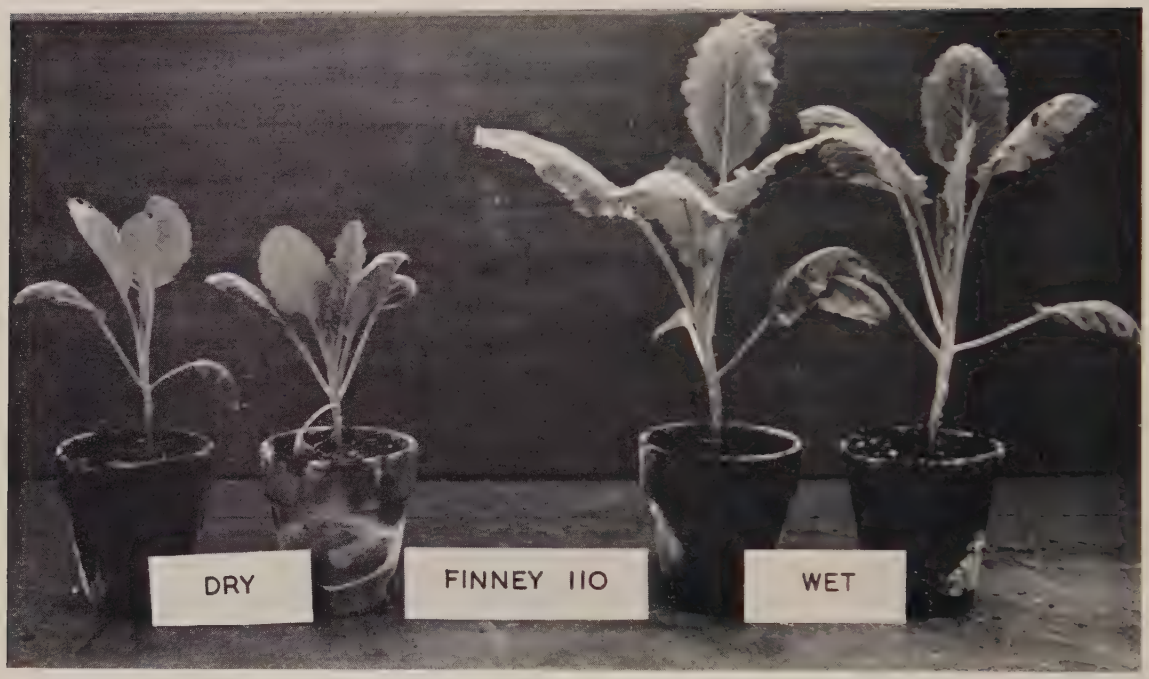

Fig. 1.

Effect of wet and dry treatments on cauliflower plants overwintered in cold frames; photograph taken at time of transplanting to the field.

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TABLE VII.

Summary of the three years' results.

	Finney's 110						Remme			
	Frame			Field			Frame		Field	
	1957	1958	1959	1957	1958	1959	1958	1959	1958	1959
Untrimmed head weight	w	**W**	**W**	**W**	w	**W**	d	**W**	w	**W**
Curd diameter	**W**	=	**W**	w	=	**W**	d	**W**	w	**W**
Mean number days after 1st May when harvested	w	**W**	**W**	w	=	w	w	**W**	d	d
Leaf number	w		**W**	w		d		**W**		w

W, wet treatment resulted in significant increase over dry treatment.
w, wet treatment resulted in non-significant increase over dry treatment.
d, dry treatment resulted in non-significant increase over wet treatment.
=, results from the two treatments were identical.

DISCUSSION.

Although the soil moisture treatments maintained during the seedling stage of growth were of an empirical nature, the dry treatment gave conditions similar to those found under commercial practice and the wet treatment prevented soil moisture from becoming seriously limiting to growth. The results in 1957 and 1959 have shown that frequent watering of the plants during the early stage of growth significantly increased the head weight and curd size at harvest, even though the treatment ended at planting time. The subsequent field treatment did not alter this effect whatever the prevailing weather conditions. In 1958 the response of the plants to the frame treatments was different from that in 1957 and 1959. It is difficult to explain these anomalous results, for it is unfortunate that in 1958 detailed records of growth and development of the plants in the frames were not made. Consequently it is not known whether the plants responded to the frame treatments in the same way as in other years, the effect then being reversed by subsequent field conditions, or whether they responded differently to the frame treatments in this year because of some seasonal environmental effect. It was noted at planting time in 1958 that visual differences in plant growth between treatments were not great, but actual measurements were not made. Thus these results suggest that the response of the plants to frame treatments may be modified by seasonal conditions.

The effect of the frequent irrigation during the winter on the size of plant at planting time, and also on morphogenesis, probably accounts for the increase in plant weight and curd size at harvest. The young plants responded quickly to the treatments in the frame and, at planting time in 1957 and 1959, there was an appreciable difference in the size of plant produced by the different treatments (Fig. 1). The larger plants resulting from the frame wet treatment appeared to withstand any adverse conditions in the field after planting much better than the smaller ones resulting from the frame dry treatment, even though these latter plants looked

tougher and had a higher dry matter content (Table I). The larger plants resulting from the frame wet treatment appeared to renew growth earlier after the planting check.

At planting time the difference in the mean leaf number per plant caused by the two treatments was not large, but differences in final leaf number were statistically significant for both varieties in 1959. In 1957 there was a non-significant difference in leaf number but the trend was similar. Parkinson (1952) obtained a similar effect on leaf number by subjecting the young plants to a 16-day dry period, but Aamlid (1952) found that dry conditions increased the final leaf number.

Although plants from the dry treatment had fewer leaves at the stage of curd initiation, this stage was not reached any earlier. On the contrary, in 1957 plants from the dry treatment were ten days later in initiating curds, and in 1959 two days later, than plants from the wet treatment. Wiebosch *et al.* (1950), however, found that dry soil moisture conditions in the early stages of growth tended to hasten curd initiation.

The final leaf number per plant was correlated with the earliness of cutting, the later maturing plants having the larger number of leaves. This agrees with the results of Aamlid (1950), Parkinson (1952) and Jensma (1957). An increase in plant weight and curd size was also associated with later maturity and with an increase in leaf number. Aamlid found that the size of curd showed a high positive correlation with the weight of leaves and with leaf number, and Salter (1959) also has found a high correlation between leaf area and curd size. Thus the increase in yield resulting from the wet treatment in the early stages of growth is most probably a result of the increase in mean leaf number per plant associated with this treatment. The field treatments could not materially alter the final leaf number, for these treatments had only just begun when curd initiation took place. It is probably for this reason that the effect of the frame treatments could not be altered by the subsequent field conditions.

The increase in yield following irrigation in the field confirms the previous results on this subject (Salter, 1959).

In 1957 a number of plants buttoned in the field but, as similar frame treatments in 1958 and 1959 gave no buttoned plants, this could not be a result of the frame treatments alone, but of other circumstances peculiar to the 1957 experiment. A combination of two factors can explain the amount of buttoning in 1957, namely, the age of the plants at planting time and the weather conditions after planting. A period of severe weather prevented the plants being planted in the field until 13th March when they were all past their best transplanting condition. The mean number of leaves present at that time was 26·0 and 23·3 for the plants from the wet and dry treatments respectively (Table I). The final leaf numbers were only 27·8 and 27·0 for the two treatments and curd initiation had already begun in a few plants from each treatment. Jensma (1957) has shown that buttoned plants in his experiments had entered the generative phase of growth at planting time, whereas those which were still vegetative when planted produced normal curds. Wiebosch *et al.* (1950) and Carew and Thompson (1948) also have found that old plants, kept past their best transplanting condition, produce a high percentage of buttons. Conditions in the field following planting were particularly dry in 1957 and the resumption of growth was affected. When plants were subjected to dry soil conditions in the frame and then dry conditions in the field a third of them produced

buttons. Both Jensma (1957) and Wiebosch *et al.* (1950) found that dry soil conditions after planting in the field were a contributory cause of buttoning.

The wet treatment was maintained throughout the winter period and the plants and soil were frequently frozen in 1957 and 1958. For example, in the 1957 experiment the minimum temperature in the frames fell to 20–25° F. on twenty-five occasions. Contrary to popular belief, the plants kept very wet did not show worse symptoms of frost damage than those kept dry ; and van Koot (1948) in fact, found that young cauliflower plants grown under dry soil conditions were more seriously damaged by frost than plants grown in moist soil during the winter months.

These experiments were carried out to determine the response of young cauliflower plants to different soil moisture conditions, as part of a wider investigation into the response of the plant to changes in soil moisture status at various stages of development. The frequent irrigation in the early growth stages was an attempt to make soil moisture non-limiting during this period and it was never envisaged that the treatment could or should be applicable commercially. Nevertheless, the results obtained in these experiments suggest that young cauliflower plants are adversely affected by dry soil conditions during the winter months and that frequent watering during this period would increase yields.

SUMMARY.

The response of early summer cauliflower plants to different soil moisture conditions during the early stages of growth was determined. In the two treatments, applied to potted plants in cold frames from October until planting time in March, frequent watering so as to maintain soil moisture at or near field capacity was compared with a dry regime in which plants were watered only when they began to wilt. After planting in the field, wet and dry treatments were given, both to plants which had been grown in wet conditions in the frames and to those which had been grown under dry conditions. Similar experiments were carried out during three successive seasons.

The wet treatment applied in the early stages of growth resulted in increased yield at harvest, increase in final leaf number per plant and a slight delay in maturity compared with the dry treatment. Irrigation in the field resulted in increased yields in two years out of three.

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THE CONTROL OF RUNNERING IN STRAWBERRIES WITH MALEIC HYDRAZIDE

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SINCE 1950 (Denisen, 1950) several reports have appeared from the U.S.A. on the use of maleic hydrazide to suppress runner production in strawberry plantations. Denisen (1956a) reported complete suppression of runner development after spraying spring-planted plants in mid-June at 2,000 p.p.m. and repeating the spray three weeks later. Under the matted bed system, which is commonly used in the U.S.A., complete runner suppression is not desirable and the more usual aim has therefore been to delay the time of spraying until runners have reached a desirable density and then to attempt to prevent the development of further runners, which would overcrowd the beds and reduce the quality of the crop. In recent reports both Denisen (1956b) and Hitz (1959) have shown maleic hydrazide to be useful for this purpose.

The experiments reported here were done to find out if maleic hydrazide could be used to give a satisfactory control of runner production under the system whereby strawberries are planted in spring in single rows and all runners developing during the summer removed. The plants are deblossomed in their first year and no crop is taken. The mats of runners formed during the summer are a nuisance to cultivation and compete strongly with the parent plants for water and nutrients. The removal of runners at regular intervals through the summer makes heavy demands on labour at a busy time and, if neglected, may result in a considerable decrease in the cropping capacity of the plantation in the following year. Alternative systems, such as the matted bed and the matted row, are not considered suitable for leafy, vigorous varieties like Talisman, owing to the difficulty of controlling grey mould during cropping.

A glasshouse experiment was done to investigate the susceptibility to maleic hydrazide of runners of different ages and to give information on the duration of the effect of one application. To provide a guide to the optimum times for spraying, records were made of the normal pattern of runner production in the field during the summer. For the treatment to be of practical use it was considered essential that runner control should be possible with no more than two sprays during the summer, and that the level of cropping should not be much reduced. The results of experiments in the field in two years are reported, in 1956 on the variety Royal Sovereign and in 1958 on Talisman and Redgauntlet.

In all the experiments maleic hydrazide was used as the triethanolamine salt. This was used in preference to the sodium salt as it is reported to be less dependent on a high relative humidity for successful uptake by the leaf (Smith *et al.*, 1955 ; Hubbard, 1955). In all the experiments the concentration used is given as that of active maleic hydrazide in the solution.

EXPERIMENTAL.

Effect of age of runner on susceptibility to maleic hydrazide.

Procedure.

A single application of maleic hydrazide was applied at four levels, 1, 2, 3 and 4 mg./plant to single-crown plants of the variety Talisman growing in 6 in. pots in the glasshouse. There was also an untreated control. The maleic hydrazide was contained in two drops, each of 0·1 ml., applied to two of the leaflets of the youngest fully expanded leaf. After application a cover slip was placed over each drop and not removed until all traces of the solution had disappeared. Each treatment was applied to twenty-four plants, of which twelve had all the runners which had emerged before treatment removed. In the other twelve plants the existing runners were retained to see if they reduced inhibition of runners emerging after treatment by lowering the concentration of maleic hydrazide in the parent crown. The experiment was divided into four blocks, each treatment being applied to three plants in each block, along with three untreated controls.

At the time of treatment, on 19th May, an elastic band was put on the youngest emerged leaf of each plant ; subsequently bands of different colours were put on the youngest leaves at approximately weekly intervals so that the rate of leaf emergence and the date of emergence of each leaf could be recorded.

At 4 mg./plant the whole plant was severely inhibited and this treatment is excluded from the results reported below.

Effect on runners already emerged or emerging.

When treated, each plant had on it three emerged runners at various stages of development. In the treatments from which they were not removed these runners were classified according to their ages as follows :

Class 1, runners just visible between stipules of leaves
,, 2, runners with the first internode elongating
,, 3, runners with the second internode elongating
,, 4, runners with one or more emergent leaves.

The development of the runners after treatment was carefully measured and on 9th June they were removed, and the number which had ceased to grow was recorded. Fig. 1 shows the percentage inhibition of each class of runner at the different levels of treatment.

The youngest runners were the most easily inhibited. The level of maleic hydrazide required for inhibition increased as the runners developed and those which had leaves of their own were inhibited only at levels which severely reduced the growth of the parent plant.

Effect on runners emerging after treatment.

In the controls a runner emerged from each leaf axil throughout the course of the experiment. In the treated plants the course of development was changed so that sometimes a branch crown emerged instead of a runner and in other cases the axillary bud failed to emerge as either runner or branch crown. Table I shows the numbers of runners, branch crowns and undeveloped axillary buds in each of the

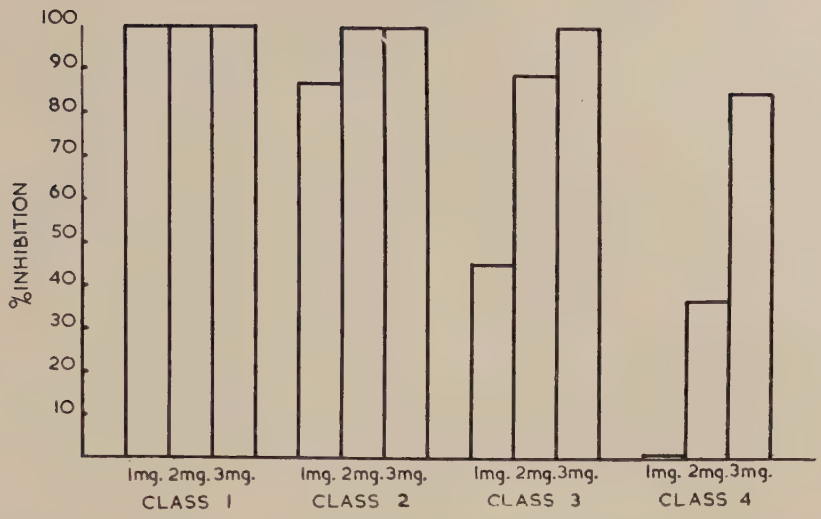

FIG. 1.

Effect of runner maturity (Class 1 youngest) on susceptibility to treatment with maleic hydrazide at 1, 2, or 3mg. per plant.

four leaves emerging after treatment. There was no difference between plants with and without runners at the time of treatment and the two sets have been combined.

TABLE I.

Development of axillary buds in the first four leaves emerging after treatment with maleic hydrazide.

Treatment per plant	Runners in 1st-4th leaves				Branch crowns				Undeveloped axillary buds			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
0 mg. maleic hydrazide	24	24	24	24	0	0	0	0	0	0	0	0
1 mg. ,, ,, ...	24	20	16	24	0	3	6	0	0	1	2	0
2 mg. ,, ,, ...	17	9	8	15	3	11	3	1	4	4	13	8
3 mg. ,, ,, ...	10	4	4	6	9	12	8	1	5	8	12	17

The effect of treatment was temporary and the number of leaves emerging before a return to normal runner initiation varied with concentration. No treatment increased branch crowns to the extent that they occupied all positions normally occupied by runners, and it was unusual to find more than two induced in any one plant. Many of the runners initiated failed to develop and the mean length attained by successive runners emerging after treatment is shown in Fig. 2.

All treatments resulted in a high initial rate of inhibition and the duration of the effect increased with concentration so that, although at 1 mg./plant an average of only two runners emerging after treatment were effectively inhibited, at 2 mg./plant the number was increased to four.

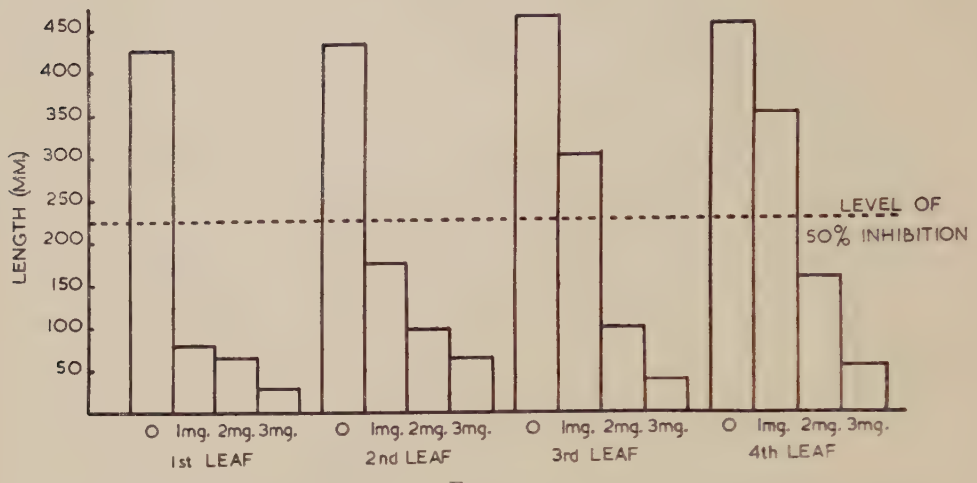

FIG. 2.

Lengths, as compared with controls (o), attained by runners in the axils of the first four leaves to emerge after treatment with maleic hydrazide at 1, 2, or 3mg. per plant.

The results of this experiment indicate that at the optimum level of application, in this case 2 mg./plant, one application of maleic hydrazide may inhibit the further development of two emerged and four unemerged runners, making a total of six runners, without severely inhibiting the growth of the parent plant. In the field there is an interval of 7 to 10 days between the emergence of successive runners from one crown so that an interval between spray applications of 6–7 weeks should be possible.

FIELD EXPERIMENT, 1958.

This experiment, though later in time, will be described first, as it was carried out in greater detail.

Pattern of primary runner production.

Runners were removed and the number recorded at intervals through the summer from 60 plants of each of the varieties Talisman and Redgauntlet planted in the field in the spring. Fig. 3 shows the rate of primary runner production as the mean number of runners produced per day per plant between different sampling dates.

The most rapid rate of runner production occurred during the second half of August but, as these runners had little time to form secondary chains, they contributed very little to mat formation. Runners emerging during July initiated large numbers of secondary runners which multiplied very rapidly during August. It is these early rooted primary runners which it is most essential to control effectively.

Procedure of spraying experiment.

Runner plants of the varieties Redgauntlet and Talisman were planted in the spring at a spacing of 4 ft $\times$ 1½ ft. in adjoining parts of the field and deblossomed in

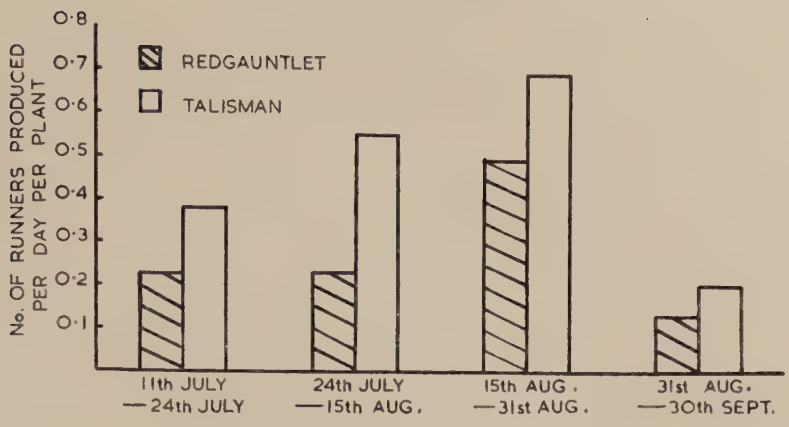

FIG. 3.
Rate of runner production in the field (1958).

their first year. The whole experiment was bounded by a guard row but no guard rows were used between different plots. With both varieties 10-plant plots were used with six-fold replication in a fully randomized block arrangement.

The plants were sprayed on 8th July with maleic hydrazide at 500, 1,000, 2,000 or 3,000 p.p.m. with 0·1% Agral added as a wetter. On 12th August half the plots of each treatment were resprayed at 1,000 p.p.m. Two controls were used : in one, all runners were removed at two- to three-weekly intervals throughout the season ; in the other, runners were allowed to grow unchecked. The sprays were applied with an Oxford precision sprayer, using nozzle size " 000 " at a pressure of 40 lb./ sq. in. and each plant was sprayed for 3 seconds. This gave a total spray application equivalent to about 60 gallons per acre. The spray was directed at the parent plants only, so that very little went to waste on the ground. The plants " wetted " well and there was very little run off. Runners were trained to one side of the row as they emerged, to prevent intermingling of runners from different treatments, thus making it possible to evaluate the effectiveness of treatment by estimating the density of runners in different plots.

The experiment was hand-weeded as required and established runners were disturbed as little as possible. During the winter all runners were rotavated in and the plantation was reduced to the original parent plants for cropping.

It was intended to apply the first spray just before the first runners rooted. Rain delayed its application for about a week so that, when treated, many plants had one or two rooting runners present. Experience has since shown that these runners should have been removed by hand, as control of secondary runners arising on them was unsatisfactory.

Effect on plant vigour.

No symptoms appeared for nearly two weeks after the first treatment, when a few inhibited runners could be found. Shortly afterwards the plants sprayed at 2,000 and 3,000 p.p.m. showed marked chlorosis of the young leaves. By 12th August most of the plants treated at 2,000 p.p.m. and all those treated at 3,000 p.p.m.

showed severe chlorosis, stunting of the growth of young leaves and some development of red tints. Talisman was more severely affected than Redgauntlet. By 1st September plants of all treatments, even those which had had a second spray on 12th August, had practically recovered their normal green colour, but many of them were stunted in height.

Measurements of the height of the plants were made to provide means of recording plant vigour. The records were made by measuring the distance from the ground between the plants to the apex of the dome formed by the leaves. This was done by mounting a cane on a retort stand so that the cane was free to pivot horizontally and to move up and down the stand. The broad base of the stand eliminated inaccuracies due to unevenness in the ground and in practice little difficulty was found in determining the position of the apex of the plant with the cane. The vertical distance from the base of the stand to the cane was then measured with a ruler mounted alongside the stand. This method of measuring vigour was chosen in preference to measurements of the breadth of the plants as it gave a result which was more in accordance with the observed appearance of the plants. The results are given in Table II.

At the lower levels treatment with maleic hydrazide increased the height of the parent plant, presumably by restricting the numbers of primary runners, but at 3,000 p.p.m. the height of all plants was quite severely reduced. The beneficial results of regular hand removal of all runners is clearly shown by a comparison of the two control treatments.

Runner inhibition.

Four independent estimates of runner density were made between 16th and 21st October. The scores from one occasion to another never varied by more than one division of the scale for any one treatment. Scores were allotted as follows :

0, plots clean of runners
1, small discontinuous groups of primary runners, secondary chains absent or very short
2, as for 1, but secondary chains better developed
3, continuous line of runners extending quarter way between the plots
4, continuous line of runners extending half way between plots
5, continuous line of runners extending three-quarters way between plots
6, full runner cover between plots.

The results are given in Table II and are the means of the four samples.

The lack of success in controlling runners of Talisman was largely due to the number of secondary runners formed on runners rooted before treatment. In both varieties the first spray inhibited primary runner development at and above the 1,000 p.p.m. level, but in Talisman the effect of sprays at and below 2,000 p.p.m. was very temporary and the second spray was almost totally ineffective.

Inhibition of primary runners in Redgauntlet was high in all except the plants treated with a single spray of 1,000 p.p.m. and at 500 p.p.m., either alone or when followed after a month by an additional treatment at 1,000 p.p.m. In all other treatments most of the runners present at the end of the season were secondary ones

TABLE II.

Experimental results following the application of maleic hydrazide in the field (1958).

	Sprayed once (p.p.m.)				Sprayed twice (p.p.m.)				Controls		Sig. diff.
	500	1,000	2,000	3,000	500 +1,000	1,000 +1,000	2,000 +1,000	3,000 +1,000	o(a)*	o(b)	
A. *Redgauntlet*											
Runner density	4·0	4·0	3·0	2·0	3·2	2·2	2·2	1·7	4·5	—	0·8
No. of inflorescences per plant	7·4	8·1	10·9	11·8	8·3	8·8	10·6	13·3	7·1	12·3	1·3
Crop picked per plant in oz.	14·7	16·0	17·8	16·7	17·5	16·3	16·9	18·8	14·1	17·4	2·9
Plant height in cm.	23·2	23·1	22·6	19·9	21·5	21·1	20·0	19·6	21·8	23·3	1·4
B. *Talisman*											
Runner density	5·2	4·5	3·7	2·5	5·0	4·2	4·0	3·0	5·7	—	0·8
No. of inflorescences per plant	9·0	10·3	13·0	18·0	12·0	13·8	14·8	17·6	9·3	18·3	1·6
Crop picked per plant in oz.	19·6	19·6	25·1	26·9	23·3	24·8	25·1	26·5	17·9	26·8	2·7
Plant height in cm. ..	20·7	21·6	21·1	18·7	20·7	21·6	20·6	18·2	18·9	23·3	1·3

* o(a), runners unchecked ; o(b), runners removed by hand.

arising from runners rooted before the start of treatment. At 3,000 p.p.m. runner inhibition was practically complete ; even when no second spray was applied, the only runners present at the end of the season were those which had rooted before the start of treatment.

Effect on flower initiation and cropping.

The crop produced in the following year was picked every three to four days and the total amount of fruit picked per plant is shown in Table II together with the number of inflorescences produced per plant. Both the number of inflorescences and the weight of fruit picked are proportional to the degree of runner control achieved, even at levels which severely reduced the height of the plants in the previous autumn. Even where runner control was unsuccessful, as with Talisman at 500 and 1,000 p.p.m., spraying with maleic hydrazide increased the crop picked.

FIELD EXPERIMENT, 1956.

Plants of the variety Royal Sovereign were planted in the spring at a spacing of 3 ft. $\times 1\frac{1}{2}$ ft. Maleic hydrazide was one of a number of growth promoters and inhibitors applied at weekly intervals between 19th July and 30th August ; only the results for maleic hydrazide are reported here. Each treatment was applied to 40 plants and the experiment was divided into 5 blocks, each treatment being replicated in each block in two plots of 4 plants each. Maleic hydrazide was applied at 250 p.p.m. with Agral added as a wetter. Application was as a dip to the youngest expanded leaves on each plant and repeated at weekly intervals.

All runners were removed in the autumn when counts were made of runner production. In the following year the crop was picked at intervals of 3 or 4 days and, after cropping, the plants were dug up and counts made of the number of crowns and inflorescences present. The results are given in Table III. Also calculated are the mean number of inflorescences initiated per crown and the mean crop weight per inflorescence.

TABLE III.

Effects of application of maleic hydrazide to Royal Sovereign; youngest expanded leaves dipped in 250 p.p.m. solution at weekly intervals.

Treatment	No. of runners per plot	Crop wt. in oz. per plot	No. of inflores-cences	No. of crowns per plot	Inflores-cences per crown	Crop wt. in oz. per inflor-escence
Control	11·3	20·4	20·5	18·8	1·10	1·00
Maleic hydrazide dips ..	6·9	31·1	31·8	27·3	1·13	1·02
Sig. diff.	3·5	6·3	—	4·0	0·1	—

The crop picked was increased in proportion to the increase in the number of inflorescences. Treatment with maleic hydrazide had no effect on the number of inflorescences initiated per crown, so that the difference in crop was entirely due to the increase in the number of branch crowns which provided more positions in which flowers could be initiated in the autumn. This confirms the result previously found

in the glasshouse, in which treatment with maleic hydrazide led to the formation of some branch crowns in place of runners.

DISCUSSION.

Studies in the glasshouse suggested that one application of maleic hydrazide could be expected to be effective against six successive runners per crown, and this expectation was confirmed by work in the field. This means that no more than two sprays should be needed to give control throughout the summer.

Denisen (1953) found that maleic hydrazide applied at the time of flower initiation caused a reduction of the crop in the following year. Experiments at Mylnefield, not reported here, have also shown interference with flower initiation immediately after treatment with maleic hydrazide. In Scotland flowers are usually initiated from the beginning of September. Since the latest date at which maleic hydrazide need be applied for runner control is mid August, it is unlikely that flower initiation would be adversely affected. This is confirmed by the results of the 1958 experiment reported above in which treatment on 12th August with maleic hydrazide at 1,000 p.p.m. had no discernible effect on flower initiation even though this began unusually early, between 22nd and 26th August.

The presence of rooted runners at the time of spraying greatly reduced the efficiency of the treatment. Experiments in the glasshouse showed that, once a runner had formed leaves, it became relatively resistant to maleic hydrazide, and in the field it was found that such runners could be controlled only at levels which caused severe inhibition to the parent plant, and that with Talisman the inhibitory effects on secondary runners was only very temporary. Radio-isotope studies by Brown and Hitz (1957) using C^{14} maleic hydrazide showed that it was very rapidly translocated from the parent plant to the runners, with no reverse movement. It seems likely that rooted runners, from which secondary runners emerge very rapidly, compete with the parent plant for maleic hydrazide and so reduce the effectiveness of the spray, and that this explains the almost total lack of response by Talisman to the second treatment. It is most important, either that the first spray should be applied before any runners have rooted or, if this stage is missed, that rooted runners should be removed before spraying.

The results of the experiments show that the effect on fruiting is directly proportional to the runner control achieved and that, at the levels used, the chlorosis and inhibition of growth in the parent plant after treatment is not reflected in the subsequent crop. Experiments in the glasshouse and field show that the increase in crop is due to the induction of extra branch crowns which act as additional sites for flower initiation in the autumn. In this respect there is a varietal difference in the degree of response between Talisman and Redgauntlet, the latter showing a much more restricted increase in crop after restriction of runner growth either by hand removal or treatment with maleic hydrazide (Table II).

SUMMARY.

The use of maleic hydrazide as a means of controlling runner production in first-year plantations of strawberries was investigated, together with its effect on subsequent cropping.

Preliminary experiments in the glasshouse showed that the level of maleic hydrazide required for inhibition of runner growth increased with maturity of the runner. They also suggested that at the optimum level one application of maleic hydrazide could be expected to prevent the successful development of two emerged and four unemerged runners, without seriously checking the growth of the parent plant.

Plants of the varieties Redgauntlet and Talisman growing in the field were sprayed at 500, 1,000, 2,000 and 3,000 p.p.m. on 8th July. On 12th August a second spray at 1,000 p.p.m. was applied to some of the plants treated previously.

Runners rooted before treatment were resistant to inhibition and reduced the effectiveness of the treatment on runners emerging later. Because of this a high level of control was achieved in Talisman only by spraying at 3,000 p.p.m. In Redgauntlet, runners were adequately controlled at all levels except 1,000 p.p.m. as a single spray and 500 p.p.m. either as a single application or followed after a month by 1,000 p.p.m.

Cropping in the following year was proportional to the degree of runner control achieved. All treated plants cropped better than controls in which runners had been allowed to grow unchecked and, at the higher levels, cropped as well as controls from which all runners had been removed by hand at intervals throughout the season.

Treatment with maleic hydrazide in the glasshouse resulted in the formation of some branch crowns in place of runners. An increase in cropping of treated Royal Sovereign plants growing in the field was due to an increase in the number of branch crowns rather than to an increase in the number of inflorescences on each branch crown.

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GRAFT INCOMPATIBILITY IN PLUMS; OBSERVATIONS ON A TEN-YEAR-OLD FIELD TRIAL

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GRAFT INCOMPATIBILITY in plums has not been a major problem in practical fruit growing and, unlike incompatibility between pear and quince, it has received relatively little detailed study. What information exists is mainly of an empirical nature, and concerns bud-take and breakage of certain stock/scion combinations (Argles, 1937), or the behaviour of established trees when top-worked (Heppner and McCallum, 1927 ; Montgomery *et al.*, 1943 ; Loewel, 1947). Fruit growers have used rootstocks like Brompton, and more recently St. Julien A, with a wide compatibility range, and have avoided those rootstock/scion combinations known to be incompatible. While research workers have continued their interest in the effects of intermediates and of reciprocal grafting, and in the possible mechanism of incompatibility, the most important practical consideration is to be able to recognize, at the earliest possible date, whether incompatibilities are likely to arise with new rootstock and scion varieties. Failing a more exact understanding of the biochemical causes which are now widely believed to underlie many of the graft incompatibilities occurring in hardy fruit trees, the most reliable guide has been the anatomical structure of the union itself (Thiel, 1954 ; Herrero, 1956 ; Mosse and Scaramuzzi, 1956 ; Gur, 1957).

Herrero (1951) reported the results of an intensive investigation, begun at East Malling in 1948, the object of which was to determine whether incompatibility in plums, pears and peaches could be forecast from the histological structure of the union in one- and two-year-old trees. The work described in the present paper arose directly from Herrero's experiment with plums, the idea being to see how far his observations on the graft unions of two-year-old trees accorded with the performance of similar trees over a much longer period.

Materials and methods.

The set of plum trees prepared was similar, both in the varieties used and in particulars of grafting, to those used by Herrero, the only difference being that they were started a year later. The details are given in Table I. Two of the four plum varieties used are compatible with the rootstock Myrobalan B (MB), viz., Victoria and President, and two are regarded as incompatible, viz., Reeves' Seedling and Oullins Golden Gage. The four varieties were used in all possible combinations of scion and intermediate.

The trees were double-grafted with a 3 in. intermediate and were cut back in the first year to produce 6 ft. standards with three to four main branches. After a second year in the nursery they were transplanted to their permanent positions at 12 ft. square, and remained there with a minimum of pruning until they were ten

TABLE I.

Details of graft combinations, all trees on Myrobalan B rootstock.

Intermediate	Scion			
	Oullins Golden Gage	Reeves' Seedling	President	Victoria
Oullins Golden Gage ..	O/O	R/O	P/O	V/O
Reeves' Seedling ..	O/R	R/R	P/R	V/R
President	O/P	R/P	P/P	V/P
Victoria	O/V	R/V	P/V	V/V

years old. One part of the experiment, with eight replicates, consisted of treatments containing the variety Reeves' ; the treatment R/R had only four replicates as some trees were used for an anatomical study. The remaining treatments had seven-fold replication. The trees were carefully staked at the time of planting, but stakes were removed when the trees were seven years old, in order to test the strength of the union under natural conditions.

In 1958 all trees were lifted. Notes were made on the internal appearance of the unions and, in the lightest and heaviest tree of each graft combination, the macroscopic structure of the union was examined in detail by sawing through the unions longitudinally and looking at the woody cylinder after removal of the bark.

RESULTS.

Some trees of some of the reputedly incompatible graft combinations, notably R/V, V/R, V/P and P/V, exhibited the usual symptoms associated with incompatibility, viz., stunted growth, sparse yellow foliage and excessive cropping, a few trees breaking off at one or other union.

The most interesting information gained from this trial concerns :

(*a*) The forecasting of breakage in mature trees by examination of two-year-old unions, and the relation between union structure in two- and ten-year-old trees.

(*b*) Incompatibility reactions arising between plum varieties used as scion and intermediate.

Union structure and breakage.

Defects in union structure which are caused by breaks in cambial continuity between stock and scion may occur at different places in the same union. Although their effects will persist, such breaks need not be permanent. Quite often cambial continuity is re-established but, after a period of normal growth, breaks may recur in either the same or another position. Such breaks follow no recognizable pattern, and this makes it difficult to assess the extent of discontinuity in a three-dimensional solid structure like a graft-union. Thus the question arises, how far does the structure of two-year-old unions foreshadow that of a mature tree, and to what extent can it be correlated with subsequent breakage?

Breakage records and the assessment of union structure in two-year-old trees (Herrero, 1951) and in the similar set of ten-year-old trees now described are shown in Table II.

TABLE II.

Assessment of union structure in two- and ten-year-old double-grafted plum trees of sixteen graft combinations on Myrobalan B rootstock, and their breaking record during ten years' growth.

Scion/ inter-mediate		Assessment of union structure		No. of trees broken
		At 2 years old (Herrero, 1957) ; mean of 4 unions	At 10 years old ; mean of 2 unions	
O/O	U	All very good	Compatible	0
	L	All with clear symptoms of incompatibility	Incompatible	1
O/R	U	Some with clear symptoms of incompatibility	Compatible	0
	L	All with clear symptoms of incompatibility	Slightly incompatible	0
O/P	U	Some with mild structural defects	Compatible	0
	L	Some with mild structural defects	Compatible	0
O/V	U	All very good	Compatible	0
	L	Some with mild structural defects	Compatible	0
R/O	U	Some with clear symptoms of incompatibility	Compatible	3
	L	All with clear symptoms of incompatibility	Incompatible	0
R/R	U	Some with mild structural defects	Compatible	0
	L	All with clear symptoms of incompatibility	Slightly incompatible	0
R/P	U	All very good	Compatible	0
	L	Some with mild structural defects	Compatible	0
R/V	U	Some with clear symptoms of incompatibility	*	8
	L	Some with mild structural defects	Compatible	0
P/O	U	All very good	Compatible	0
	L	Some with clear symptoms of incompatibility	Incompatible	0
P/R	U	Some with mild structural defects	Compatible	0
	L	Some with clear symptoms of incompatibility	Slightly incompatible	0
P/P	U	All very good	Compatible	0
	L	Some with mild structural defects	Compatible	0
P/V	U	Some with mild structural defects	Slightly incompatible	2
	L	Some with mild structural defects	Compatible	0
V/O	U	All very good	Compatible	0
	L	Some with clear symptoms of incompatibility	Incompatible	0
V/R	U	Some with clear symptoms of incompatibility	Compatible	0
	L	All with clear symptoms of incompatibility	Very incompatible	1
V/P	U	Some with clear symptoms of incompatibility	Slightly incompatible	1
	L	Some with clear symptoms of incompatibility	Incompatible	1
V/V	U	All very good	Compatible	0
	L	Some with mild structural defects	Compatible	0

O, Oullins Golden Gage ; R, Reeves' Seedling; ; P, President ; V, Victoria. U, upper union, between top-scion and intermediate ; L, lower union, between intermediate and rootstock.

* No assessment of union structure in 1958, as all trees had broken.

Graft combinations which were found by Herrero to have made very good unions in two-year-old trees exhibited the same quality in ten-year-old trees ; no deterioration had occurred in the older trees but rather the reverse. With one notable exception to be discussed later, this general similarity between the classification of unions in two-year-old and ten-year-old trees and this trend towards improved structure of unions applied equally to the less compatible groupings. This indicates that a graft combination which has a satisfactory union structure when two years old can be recommended for orchard planting with reasonable safety. The gradual lignification of parenchymatous areas between stock and scion, together with the cumulative effects of any vascular connections that are formed, leads to an actual strengthening of the union as the tree matures. In addition it seemed as if some adaptation of one or both graft components had occurred in some unions, since breaks in cambial continuity occurred less frequently.

Although the trees were planted in an exposed position, had grown well, and were unstaked during the last three years of the trial, only seventeen broke out of a total of 115 trees. There was no positional effect and all breakages can be directly related to weak unions. Nine broke during a severe gale in September 1956 ; it is of interest that unions commonly considered incompatible, viz., Oullins on Myrobalan B and Reeves' on Myrobalan B, gave no breakages on this occasion despite the fact that some trees were blown right over. The trial contained 107 unions classified as incompatible on the basis of Herrero's report ; only fifteen broke. Twelve of these fifteen breakages occurred in the upper union and were due to interactions between scion varieties ; only three were due to interactions between the Myrobalan B rootstock and a variety.

All unions between Oullins and Myrobalan B showed a high degree of discontinuity, both at two- and ten-years old, but only one broke, and even this was not a completely smooth break. Equally the prediction of weakness in unions of Reeves'/Myrobalan B proved correct only if the top-scion was Victoria, whereas with the other three top-scions there was no breakage and even some evidence of improvement in union structure in the older trees. The outstandingly incompatible combination was Reeves'/Victoria, all eight trees breaking at the upper union. This precluded their re-examination at the later date, but the combination, while classified as incompatible in 1949, would not have been singled out at that time as the one most likely to break. Although many of the unions forecast as incompatible did develop considerable structural defects, these were insufficient to lead to breakage. If the breakages and the individual unions are arranged according to graft components involved in each union the results set out in Table III are obtained. Thus any unsatisfactory union containing Victoria as one graft component is more liable to break than others equally unsatisfactory. It has already been suggested that there is a gradual strengthening of incompatible unions due to various factors, one of which is the cumulative effect of any vascular connections that are formed. The strength of such connections depends on their cross-sectional area and the inherent strength of their constituent tissues. It is known that the branches of certain plum varieties are brittle and very prone to break while others are very strong, and this varietal character is probably determined by their wood structure. Victoria is outstandingly brittle while Oullins and Myrobalan B hardly ever break. It is suggested that, while breakage in the nursery is largely determined by the total area of unconnected vascular tissue at the union, the strength of any connections that are

TABLE III.

Number and percentage of breakages in relation to graft components.

	Variety				Rootstock Myrobalan B
	Victoria	Reeves' Seedling	President	Oullins Golden Gage	
Unions classified as incompatible by Herrero on two-year-old trees	22	64	29	44	65
Breakages in ten years	11	12	4	4	3
Percentage broken	50	18·8	13·8	9·1	5·6

formed may become an increasingly important factor in determining the union strength of older trees. If this is so, particular attention must be paid even to mild symptoms of incompatibility in young unions when one of the graft components is known to suffer from brittleness.

Out of 131 unions classified as compatible two broke in the field. Both belonged to the combination P/V and broke in the upper union ; this result, together with other field observations, has led to the conclusion that these two varieties must be regarded as incompatible, although this was not apparent at two years.

Interactions between varieties.

Table II indicates that reciprocal incompatibility exists between the following pairs of varieties : Victoria and Reeves', Victoria and President, Oullins and Reeves'. The first of these is the most extreme and there is evidence from the combination V/R/MB that it had increased the incompatibility of the R/MB union. The breakage records indicate that the incompatibility which develops in trees of V/P/MB is not only an induced incompatibility in the normally compatible P/MB union, as had at first been believed, but also that there is incompatibility in the V/P union. The extreme variability of symptom expression among trees of both the combinations V/P/MB and P/V/MB remains one of the most puzzling features.

The prevalence of incompatibility between plum varieties is interesting and unsuspected. If the time should come when the use of an outstanding plum stock would offer overwhelming advantages, the use of suitable intermediates for overcoming incompatibility would have to be carefully investigated, and intermediate rootstocks rather than varieties might have to be considered. For the same reason the practice of top-working is liable to lead to unexpected failures due to incompatibility.

SUMMARY.

A field trial of ten-year-old double-grafted plum trees of compatible and incompatible graft combinations is described.

On the whole there was a good correlation between union structure of two- and ten-year-old trees, but breakages occurred in one combination at ten years which had shown little sign of incompatibility when two years old.

Union structure showed a general tendency to improve as the trees became older, and of 107 unions classified as incompatible when two years old only 15 broke. A high proportion of the breakages occurred in incompatible unions where the variety Victoria was one of the graft components. The theory is advanced that in older trees the ultimate strength of an incompatible union is related, in addition to the cross-sectional area of vascular connection established, to the varietal characteristics of wood structure.

Incompatibility between different plum varieties was found to be prevalent.

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WEED CONTROL WITH DINOSEB (AMINE) IN RUNNER AND FRENCH BEANS

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THE only method of chemical weed control at present recommended in Britain for use in crops of runner and French beans is that of contact pre-emergence spraying (British Weed Control Council, 1958). Although this method is often useful, there is a need for a technique which will give control for a longer period so that the necessity for hand hoeing within the crop rows is eliminated.

Runner and French beans are damaged by all the selective post-emergence sprays at present used in other crops, and they are also susceptible to the majority of residual herbicides. In the U.S.A., however, residual pre-emergence spraying with dinoseb (amine) (alkanolamine salts of 2-*sec*-butyl-4,6-dinitrophenol) has been practised commercially for a number of years in beans and in other large-seeded crops. To determine whether this treatment would be practicable under British conditions, an experiment was carried out in 1956 using rates of 3 and 6 lb. per acre. Good weed control without crop damage was achieved and, in the following three years, twelve further field experiments were conducted. The present paper summarizes the results obtained.

Methods.

All the experiments were on a sandy loam at N.V.R.S., Wellesbourne, except for one at the N.A.A.S. Experimental Horticulture Station, Efford, Lymington, Hants. The soil at Wellesbourne is a sandy loam of the Newport series, relatively low in organic matter, while that at Efford is a fine sandy loam of the Brickearth type. The experiments were of randomized block design with three or four replications and a plot size ranging from 6 to 24 square yards. The crop seeds were sown by hand at the normal depths, either in drills drawn by a hoe or with a dibber. A proprietary formulation of the triethanolamine salt of dinoseb was employed, and all rates of application are expressed as lb. per acre of dinoseb. On dwarf French beans and on " pinched " runner beans the sprays were applied overall with a knapsack sprayer and at a volume rate of 100 gallons per acre. On runner and climbing French beans grown on strings, a band treatment over the rows only was applied. All spraying was done during the interval between sowing and crop emergence.

All plots were inter-row cultivated as necessary, leaving a band of undisturbed soil 4 or 6 in. wide over the rows, and two sets of unsprayed control plots were included in each experiment. One of these received inter-row cultivation only ; the other was weeded by hand within the rows. Weed kill was assessed by counting survivors in a number of random quadrats on each plot just before the first inter-row cultivation and, in most experiments the fresh weight of weed present at the end of harvest was also recorded. Effects on the crops were measured by counts made

during emergence, counts of plants reaching particular stages of growth, and by the weights of beans and haulm. The beans were picked regularly, and the yield figures represent totals picked on up to 20 occasions. A satisfactory level of yield was attained in the experiments.

Results.

Weed control.

Good control of annual weeds with pre-emergence applications of dinoseb (amine) was obtained in all experiments. The minimum kills recorded were 72 and 90% for rates of application of 3 and 6 lb. per acre respectively. In Fig. 1, a comparison is shown between the percentage reduction in weed weight at the final harvest and the percentage weed kill recorded before the first inter-row cultivation. There

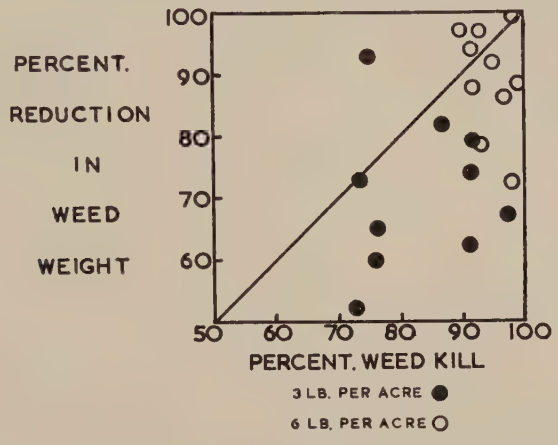

Fig. 1.

Relationship between weed weight at the end of harvest and initial weed kill.

was a tendency, particularly at the lower levels of kill, for the reduction in weed weight to be less than would be expected from the reduction in numbers. This was due in part to the fact that the survivors grew large in the absence of competition from other weeds, and in part to the presence of some weeds which became established after the residual effect of the herbicide had disappeared. Nevertheless, 3 lb. per acre always resulted in reductions in weed weight of more than 53%, and when 6 lb. per acre was applied the minimum reduction was 73%.

Senecio vulgaris, Chenopodium album, Stellaria media, Spergula arvensis and *Fumaria officinalis* proved to be very susceptible. *Polygonum aviculare, Trifolium repens* and *Poa annua* were less readily killed, and 3 lb. per acre was sometimes insufficient to give adequate control of these species.

In four experiments, application immediately after sowing was compared with application just before crop emergence. There was little difference in the kill of dicotyledonous weeds obtained, although it was slightly greater with the later spraying. There was a less consistent result with *Poa annua*, and it appeared that with this species the stage of germination at the time of spraying was important. In

general, however, 3 lb. per acre resulted in more than 50% kill of *Poa annua*, while 6 lb. per acre killed more than 80%.

Effect on runner beans.

In 1957 a small experiment was carried out with Kelvedon Wonder runner beans grown on strings in which dinoseb (amine) was applied as a band treatment just before emergence at rates of 3 and 6 lb. per acre. Excellent weed control was obtained, and yields did not differ significantly from those of control plots which had been hand-weeded. This promising result was followed up in three further experiments, the results of which are summarized in Table I.

TABLE I.

Effect of pre-emergence sprays of dinoseb (amine) on runner beans.

Treatment	Mean weight, kg. per plot					
	1958		1958		1959	
	Crop	Haulm	Crop	Haulm	Crop	Haulm
Dinoseb (amine)—						
3 lb. per acre	16·4	12·8	14·5	9·9	5·6	7·4
6 lb. per acre	15·9	10·3	15·3	10·9	5·5	7·9
Control, hand-weeded	20·0	12·3	13·2	9·7	5·5	8·1
Control, inter-row cultivation	5·3	4·9	10·3	8·1	1·7	3·5
S.E. of diff. between one treatment and a control	±1·15	±0·79	±0·75	±0·94	±0·43	±0·99

The first experiment in 1958, with var. Streamline grown on strings, was sprayed a week after sowing. During the period between spraying and the beginning of emergence, a total of 0·90 in. of rain fell and, although there was no effect on the number of plants that finally emerged, it was observed at the unifoliate leaf stage that plants on plots which had received 6 lb. per acre appeared smaller than those on other plots. This was confirmed by leaf measurements, and counts at intervals of the numbers of plants reaching the tops of the strings showed that this treatment had caused a delay of about 4 days. Maturity was also affected and the final bean and haulm weights were reduced below those from the hand-weeded control plots. The yield depression which occurred on plots treated with 3 lb. per acre appeared to be attributable to weed competition at a late stage rather than to any effect of the herbicide, and it was only on the last few picking occasions that the yield fell off in relation to that of the hand-weeded control plots.

In the second 1958 experiment, at Efford E.H.S., var. Streamline was grown as a " pinched " bean crop. Although 1·5 in. of rain fell between spraying and full emergence, there was no adverse effect of any kind on the crop and complete kill of annual weeds was obtained with both rates of application. The treatments did not affect maturity, or crop quality as measured by the proportion of Grade I beans. The main weed present was *Senecio vulgaris* and, in order to prevent seeding, this was removed from the control plots which should have received inter-row cultivation only. Even so, the yield from these plots was less than that from any of the others.

The 1959 experiment, with var. Streamline grown on strings, was carried out during dry weather. There was light rain shortly after spraying and two irrigations of approximately 0·5 in. were applied, one at 50% emergence and the other at full emergence. The spray treatments had no effect on rate of emergence, maturity or yield, but weed competition was severe and the yield was drastically reduced on the plots which received inter-row cultivation only.

Two experiments were carried out with " pinched beans ", one in 1958 with Streamline and the other in 1959 with Kelvedon Wonder, in which the effects of spraying immediately after sowing and just before emergence were compared. The results are shown in Table II. In 1958, the rainfall between the two spraying

TABLE II.

Effect of sprays of dinoseb (amine) applied immediately after sowing or just before emergence on runner beans and on weeds.

Treatment	Mean weight, kg. per plot					
	1958			1959		
	Crop	Haulm	Weeds	Crop	Haulm	Weeds
Dinoseb (amine)—						
After sowing:						
3 lb. per acre	10·89	7·18	1·92	6·82	4·21	6·28
6 lb. ,, ,, ...	11·88	7·60	0·65	10·20	6·31	2·81
Before emergence:						
3 lb. per acre	12·06	7·90	2·10	9·15	6·59	2·71
6 lb. ,, ,, ...	8·89	5·62	0·75	8·00	6·58	3·58
Control, hand-weeded	12·26	8·41	0·38	9·94	7·39	0·71
Control, inter-row cultivation ..	7·36	5·00	5·59	0·38	0·47	13·15
S.E. of diff. between one treatment and a control	±0·710	±0·549	±0·651	±1·430	±0·727	±1·300

occasions amounted to only 0·17 in., but during the two weeks following the second spraying 0·95 and 1·26 in. were recorded. Observations on the numbers of plants emerging and the numbers reaching a height of 12 in. revealed no adverse effect of the early spraying, nor of 3 lb. per acre applied just before emergence. When 6 lb. per acre was applied just before emergence, however, there was a retardation in early growth which was subsequently reflected in reduced yield. This is evident from Fig. 2*a* in which the cumulative yields on the different picking occasions are shown for the hand-weeded control plots and for those sprayed just before emergence.

In Fig. 3*a*, the total crop weights (beans plus haulm) have been plotted, on a logarithmic scale, against the weed weights at the end of harvest, also on a logarithmic scale. Each point represents the total of four replicate plots and points have been inserted separately for the two sets of both hand-weeded and inter-row cultivated control plots that were included in this experiment. The points are satisfactorily fitted by a curve of the type described by Bleasdale (1956). The point representing 6 lb. per acre applied just before emergence is shown as an open circle, and it is again clear that this treatment had a directly injurious effect on the crop.

The 1959 experiment was carried out during dry weather and no irrigation was given until a month after emergence. The treatments gave complete control of

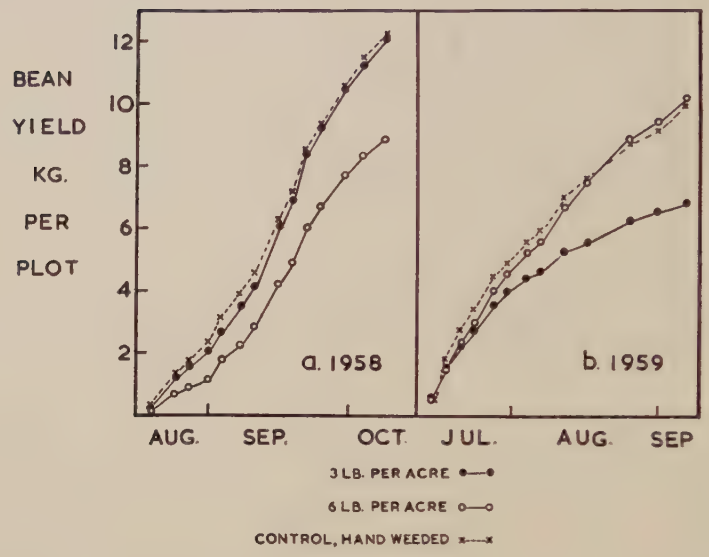

FIG. 2.
Effect of pre-emergence sprays of dinoseb (amine) on the yield of runner beans.

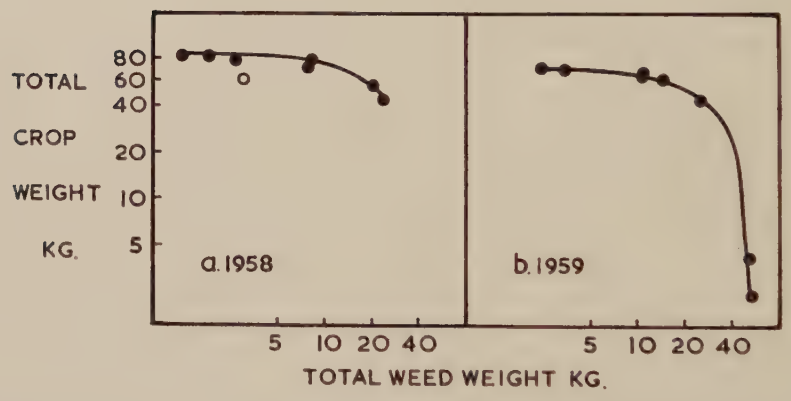

FIG. 3.
Relationship between total crop weight (beans plus haulm) and weed weight at the end of harvest.

Chenopodium album, but some plants of *Polygonum aviculare* survived and these accounted for the relatively high weed weights recorded at the end of the experiment. Cumulative yield curves for the hand-weeded control plots and for the two treatments applied immediately after sowing are shown in Fig. 2*b*. During the early part of the picking season there was little difference between the curves, but later on, as weed competition began to take effect, that for the 3 lb. rate diverged from the others. The relationship between total crop weight and weed weight is shown in Fig. 3*b*, from which it appears that the variations in yield observed in this experiment were entirely attributable to variations in weed competition, and that there was no direct adverse effect of the herbicide on the crop.

Effect on French beans.

Four experiments were conducted in which dinoseb (amine) sprays were applied pre-emergence to either The Prince or Masterpiece dwarf French beans, and the results are summarized in Table III.

TABLE III.

Effect of pre-emergence sprays of dinoseb (amine) on dwarf French beans.

Treatment	Mean weight of beans, kg. per plot.			
	1957	1958	1958	1959
Dinoseb (amine)—				
After sowing:				
3 lb. per acre	—	14·1	9·4	5·1
6 lb. ,, ,, ...	—	11·2	9·2	5·0
Before emergence:				
3 lb. per acre	3·5	12·3	9·3	—
6 lb. ,, ,, ...	3·6	10·9	9·3	—
Control, hand-weeded	3·1	13·0	9·7	4·6
Control, inter-row cultivation	2·4	10·0	8·5	5·0
S.E. of diff. between one treatment and a control	±0·47	±0·70	±0·59	±0·50

In the 1957 experiment the sprays were applied just before crop emergence and excellent weed control was obtained. The crop yields were similar to those from plots which had been hand-weeded. In 1958, spraying immediately after sowing was compared with spraying just before emergence in two experiments. In the first, 0·47 in. of rain fell during the week between the two applications and spraying just before emergence was followed by 1·4 in. during 48 hours. Counts of plants emerging on plots treated with 3 lb. per acre showed that there was only one day's delay in 50% emergence, but where 6 lb. had been applied the delays were 2 and 4 days respectively for the early and late applications. There was a corresponding delay in maturity, and yields from the 6 lb. per acre plots were depressed in comparison with those from the hand-weeded control plots.

The second 1958 experiment was adjacent to the first but was begun three weeks later. Between the two spraying occasions 0·17 in. of rain fell and there was 0·96 in. during the week following the second application. There was, however, no adverse effect of the herbicide on emergence, maturity or yield. In both experiments the

main weed present was *Senecio vulgaris* which reached maturity and died before the end but had only small effects on the yield from plots which received inter-row cultivation only. The 1959 experiment coincided with a very dry period and was not irrigated. Few weeds appeared, and neither of the spray treatments applied immediately after sowing had any adverse effect on the crop.

In a further experiment in 1959, the response of five varieties of dwarf French beans to pre-emergence sprays of dinoseb (amine) was investigated. The sprays were applied immediately after sowing and were followed by light rain. An irrigation of approximately 0·5 in. was given at the start of emergence and was repeated a week later. The final yields obtained are shown in Table IV, and it is clear that

TABLE IV.

Effect of pre-emergence sprays of dinoseb (amine) on five varieties of dwarf French beans.

Treatment	Mean weight of beans, kg. per plot					
	Master-piece	Top crop	Tender-green	Double Princess	The Prince	Mean
Dinoseb (amine)—						
3 lb. per acre	13·34	10·44	7·98	7·22	9·99	9·79
6 lb. ,, ,, ...	13·40	10·13	7·76	6·80	10·32	9·68
Control, hand-weeded ..	14·25	10·49	7·98	7·11	10·26	10·01
Control, inter-row cult. ..	13·27	9·83	7·02	6·15	9·40	9·13

S.E. of diff. between two treatments within one variety ±0·494.
S.E. of diff. between two means ±0·221.

with no variety was there any significant injury as a result of spraying. Very few weeds were present, yet the mean yield from plots which received inter-row cultivation only was significantly less than that from plots which were sprayed or hand-weeded. A small experiment carried out at the same time with Blue Lake climbing French beans also showed that dinoseb (amine) at 3 and 6 lb. per acre did not affect yield, although there was slight delay in emergence where 6 lb. per acre had been applied.

DISCUSSION.

Runner and French beans are normally sown from mid-April to the beginning of June and the main purpose of a herbicide treatment would be the elimination of the flush of weeds that emerges with the crop. This object was achieved in the present experiments to the extent that the minimum kill recorded was 72%, while kills greater than 90% were often obtained. Although further weed emergence sometimes occurred after the herbicide had ceased to be present in the soil in phytotoxic amounts, it is evident from Fig. 1 that, in general, a satisfactory degree of control was maintained throughout the life of the crop.

In these experiments, all plots were cultivated between the rows, but no hand weeding was carried out on the sprayed plots. The net effect on yield of substituting spraying for hand weeding can thus be measured by comparison with the control plots which were hand-weeded in the rows. Those control plots which only received

inter-row cultivation provide a measure of the extent of competition from the natural weed population. It has been stressed (Woodford, 1950) that, in the evaluation of a herbicide, data should be obtained separately for the weeds and the crop, as it is difficult to distinguish any effect of the herbicide on crop yield from that of weed competition when the two are growing together. In the present experiments, where yield records on a number of successive picking occasions were taken, this distinction is apparent from the form of the cumulative yield curves (Fig. 2). Graphs of the relationship between crop weight and weed weight of the kind shown in Fig. 3 also provide an indication of whether variations in yield can be attributed solely to weed competition.

In none of the experiments was there any effect of the herbicide on the final number of bean plants that emerged, and in most instances there was no adverse effect on rate of emergence, growth, maturity, bean yield or haulm weight. In three out of the twelve experiments, however, it was observed that treatment with dinoseb (amine) at 6 lb. per acre retarded emergence, that the plants subsequently remained smaller and the yield was reduced. All three experiments were in the wet year of 1958 and heavy rainfall occurred during the period between spraying and full emergence. Davis and Selman (1954) have shown that greatest leaching of dinoseb (amine) from the top inch of soil takes place when there is a rapid rate of water movement through the soil, and it appears that the heavy rain caused leaching of the highly soluble herbicide down to the zone of the seedling roots. Even under these conditions, however, the maximum yield reduction that occurred was no greater than 30% and when only 3 lb. per acre was applied there was no adverse effect on yield that could be attributed to the herbicide. The absence of damage with 6 lb. per acre in the experiment at Efford (Table I), even though there was heavy rainfall, is probably attributable to the fact that the rate of water movement in the Efford soil is much slower than that at Wellesbourne. For the experiments as a whole, the average yield from the sprayed plots was 97% of that from the hand-weeded control plots and, without exception, yields from sprayed plots were greater than those from plots which received inter-row cultivation only.

The initial kill of weeds was usually greater with 6 lb. per acre than with 3 lb. and late-germinating weeds were more effectively suppressed by the higher rate of application. On grounds of cost and because of the risk of damage with 6 lb. per acre when followed by heavy rainfall, it would appear that a rate of 3–4 lb. per acre would be a suitable practical compromise. The rate of 4 lb. per acre, although not employed in these experiments, has given good results in other experiments with peas. The comparisons of spraying immediately after sowing with spraying just before emergence did not reveal any marked consistent differences either in weed control or crop response. Spraying immediately after sowing would be easier to carry out in practice and could be combined with drilling where a self-propelled drill is used. The risk of crop damage would be minimized by sowing as deeply as is consistent with good practice.

If the whole crop area were sprayed, the cost of applying dinoseb (amine) at the suggested rate of 3–4 lb. per acre would be relatively high compared with that of herbicides available for use in other crops. The wide spacing of bean rows would, however, permit the use of a band application over the rows only, with a corresponding reduction in the cost of material. Besides the relatively high cost, dinoseb has the disadvantage of being poisonous, and its handling and use are subject to the

provisions of the Agriculture (Poisonous Substances) Regulations. Nevertheless, the successful results from this series of experiments indicate that dinoseb (amine) is a promising residual pre-emergence treatment for annual-weed control in runner and French beans. As with any pre-emergence technique, however, further trials under a wider range of soil and weather conditions and with other varieties will be necessary before it can be recommended for large-scale use.

SUMMARY.

1. The use of dinoseb (amine) as a residual pre-emergence herbicide for annual-weed control in runner and French beans was investigated in twelve field experiments.

2. Rates of 3 and 6 lb. per acre of actual dinoseb gave excellent results on most dicotyledonous weed species and a partial kill of *Poa annua*.

3. At 3 lb. per acre, dinoseb (amine) had no adverse effect on emergence, growth, maturity or yield of runner, dwarf French and climbing French beans. In most experiments 6 lb. per acre was similarly without adverse effect but, when spraying with this rate was followed by heavy rain, some retardation of growth and depression of yield occurred. This yield depression was never greater than 30%, and the yields were always higher than those from control plots which received inter-row cultivation only.

4. The experiments suggest that 3–4 lb. per acre applied as a band treatment over the rows immediately after sowing would be a useful method of chemical weed control in these crops, worthy of further testing under a wider range of conditions.

ACKNOWLEDGMENT.

Thanks are due to the Director and staff of Efford Experimental Horticulture Station for carrying out the experiment on runner beans, and the assistance in the field of Mrs. A. H. T. George, Miss S. M. S. Hird and Miss U. W. Laurence at Wellesbourne is gratefully acknowledged.

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FURTHER OBSERVATIONS ON THE EFFECTS OF RING-GRAFTING PEACHES WITH AN INCOMPATIBLE ROOTSTOCK VARIETY

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THERE is evidence that the incompatibility between peach varieties and plum rootstocks of the Myrobalan type is different in kind from that which occurs in other deciduous fruit trees. This view is based on three observations : (1) the severity and sudden appearance of incompatibility symptoms (Garner and Hammond, 1938), (2) the lack of proportion between the severity of symptoms and the extent of structural defects in the graft union (Herrero, 1951), and (3) the translocation of causal factors across a mutually compatible intermediate (Mosse, 1955 ; Herrero, 1955). The latter observations were based on a few trees only and seemed to merit further investigation. A trial was therefore designed to study the reciprocal effects of Hale's Early peach and Myrobalan B when separated by a stem piece of the mutually compatible rootstock Brompton.

Material and methods.

The technique of ring-grafting was used in the construction of the trees. Essentially this consists of the removal of a ring of bark, and its replacement by a bark ring of another variety (Fig. 1). After the latter has become established, its cambium gives rise to normal wood and bark tissue (Mosse, 1953) and a few years later, when the central woody core has become relatively insignificant, tissues derived from this cambium effectively constitute an intermediate stem piece. Ring-grafts differ from intermediates established by double-grafting in being generally shorter and in being liable to split. If splitting occurs they cease to form complete rings but remain only as stem sectors separated by other sectors which arise from rootstock tissue and develop into vertical connecting links or " bridges " between the rootstock tissue above and below the ring (Mosse, 1953). In addition to complete ring-grafts the effect of partial rings (" patches ") was also investigated. Normally bark rings do not contain buds, but in one treatment which was intended to furnish foliage of the ring-graft variety, bark patches containing a bud were used. The seven treatments are shown in Table I.

There was one additional treatment (Hale's Early on Brompton, ring-grafted with Brompton from an incompatible source) intended to test whether this type of incompatibility was graft transmissible. Owing to limited amounts of suitable ring-graft material only five such trees were available and this number proved insufficient to warrant any conclusions.

Trees were constructed as shown in Fig. 1. A bud of the scion variety was placed into the Brompton stem 9 in. above ground level, and at the same time a ring- or patch-graft, 1 in. high, was inserted into the rootstock stem 4 in. below the bud.

TABLE I.

Particulars of grafting of experimental trees.

Treatment	Scion	Ring-graft	Rootstock	No. of trees
A	Hale's Early	Brompton	Brompton	15
B	,, ,,	Myrobalan B	,,	15
C	,, ,,	,, patch-graft	,,	15
D	,, ,,	,, patch-graft with bud	,,	15
X	Myrobalan B	Brompton	,,	10
Y	,,	Hale's Early	,,	10
Z	,,	Hale's Early patch-graft	,,	10

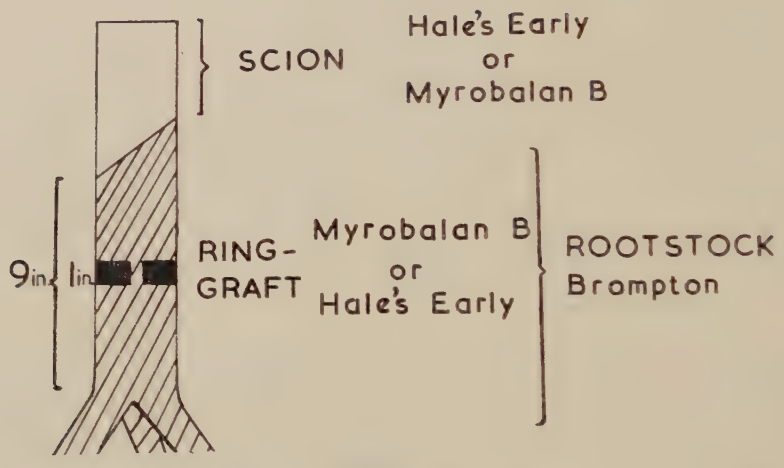


FIG. 1.

Diagram illustrating the construction of trees ring-grafted in the rootstock stem (sectional view).

Patches were approximately 1 in. wide and occupied $\frac{1}{4}$–$\frac{1}{3}$ of the rootstock circumference. Sixteen months after budding, the trees were planted in their permanent positions, 4 ft.×6 ft. apart, in five randomized blocks. Trees with Hale's scions were replicated three times in each block, those with Myrobalan B scions twice. The trial continued till the trees were five years old. During this period they received the minimum of pruning, which consisted mainly of the removal of dead wood from the Hale's scions and of water shoots from the main stems of the Myrobalans.

Observational records on growth, leaf colour and density, amount of blossom and configuration of the unions were made periodically, and in the last two years the number and weight of the peach crop were recorded. At the conclusion of the trial the above-ground parts of the trees were weighed and all unions were examined macroscopically. Notes were made on the structure of the bud unions, the upper and lower unions of the ring grafts, and the amount of bridging that had occurred. This was estimated by visual examination of planed sections cut transversely through the middle of the ring or patch. The bright yellow colour of the outer bark of Hale's

Early peach made it easily distinguishable from the Brompton rootstock. Myrobalan B tissue was distinguishable from Brompton by its pure white colour when freshly cut. The bark structure of Myrobalan B and Hale's ring-grafts was compared anatomically with normal tissue of the two varieties taken from scion stems of compatible trees.

RESULTS.

Trees in this trial were of two kinds, those with scions of Hale's Early peach (A-D of Table I), and those with scions of Myrobalan B (X-Z). Although measures were taken to force them into growth, buds on the rings in treatment D remained dormant. In spite of this, effects of the two patch-graft treatments (C and D) differed and they will therefore be considered separately. The results of incompatibility induced by ring-grafting were reflected in growth and cropping and in the anatomical structure of unions and ring-grafts. Symptoms were less severe than when Hale's Early and Myrobalan B are placed in direct contact.

Growth and cropping of trees with Hale's Early scions.

The mean final weights given in Table II show that ring-grafting with an incompatible rootstock variety reduced tree weight by approximately one third ($B<A$, $P<0{\cdot}001$).

TABLE II.

Effect of ring- and patch-grafts on tree weight (lb.) of Hale's Early peach.

Treatment	A Brompton ring-graft	B Myrobalan B ring-graft	C Myrobalan B patch-graft	D Myrobalan B patch-graft with bud
Mean weight of above-ground portions	21·7	13·6	21·7	19·2

No trees died as a result of incompatibility induced by ring-grafting, but some with sparse foliage and much dead wood looked so sick that their future was in question. None of the Myrobalan B rings remained complete, but Brompton bridges occupied from $\frac{1}{6}$ to $\frac{2}{3}$ of the cross-sectional area. There was no evidence that the establishment of bridge tissue had improved tree growth ; if anything, the incompatible trees were the more extensively bridged. Patch-grafts (C and D) did not affect the weight of the five-year-old trees.

There was an indication that grafting with Brompton rings taken from an incompatible tree, similar to those in treatment B, had adversely affected tree size. Since, however, only five such trees were available the evidence is not conclusive and requires confirmation.

Cropping figures for the last two years of the trial are given in Table III.

In 1959 trees in treatment C cropped twice as heavily as A (control) trees ($P<0{\cdot}01$), and a similar difference approaching statistical significance at the 5%

TABLE III.

Effect of ring- and patch-grafts on weight of crop (lb.) of Hale's Early peach.

Treatment	A Brompton ring-graft	B Myrobalan B ring-graft	C Myrobalan B patch-graft	D Myrobalan B patch-graft with bud
Mean per tree 1958	0·77	1·21	1·38	0·99
Mean per tree 1959	2·8	2·6	5·7	2·4
Mean per unit weight 1959	1·3	1·9	2·7	1·3

level occurred in 1958. In that year trees ring-grafted with Myrobalan B bore more fruit than controls, and in 1959 the two had similar crop weights, but it must be remembered that by this time control trees were half as large again. Both ring- and patch-grafting with Myrobalan B increased the crop per unit weight of tree. Patch-grafts with buds had no effect on tree size or crop weight and this apparent effect of a dormant bud is very curious. The result is, however, supported by developmental differences in patches with and without a bud. Where a bud was present the patch-grafts remained entire and only three out of ten developed very small bridges, whereas all the grafts without buds became extensively bridged. This result will be further discussed below.

Growth of trees with Myrobalan B scions.

In these trees the effect of bark rings of Hale's Early on the growth of Myrobalan B scions was investigated. None of the ring-grafts remained complete and the mean final weights (Table IV) failed to demonstrate any effect of incompatible ring-grafts on tree size.

TABLE IV.

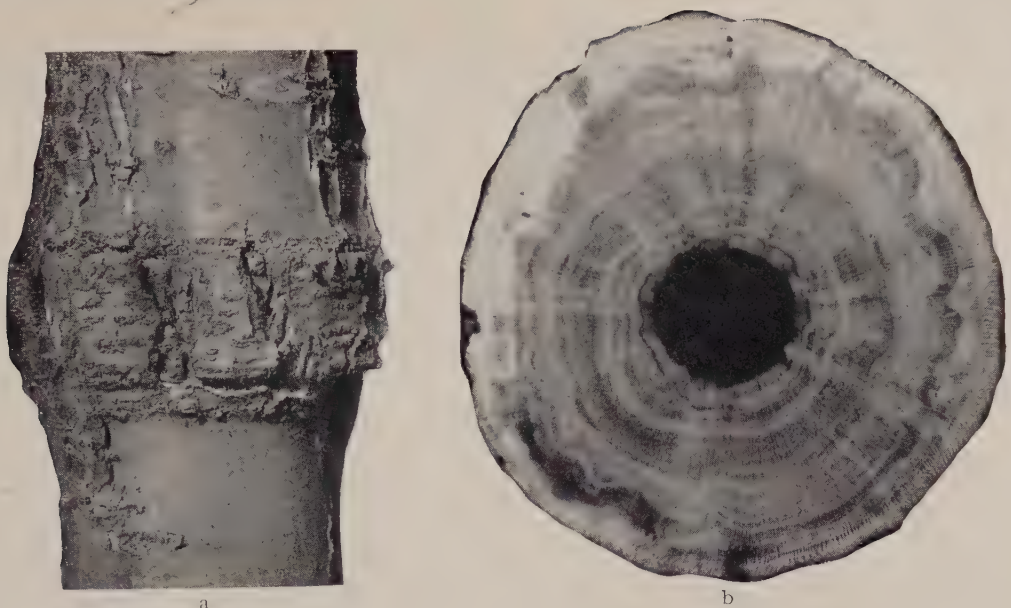
Effect of ring- and patch-grafts on tree weight (lb.) of Myrobalan B plum.

Treatment	X Brompton ring-graft	Y Hale's Early ring-graft	Z Hale's Early patch-graft
Mean weight of above-ground portions ..	25·1	21·6	25·9

Trees in treatment Y were, however, much more variable than those in the other two treatments, and a clear correlation ($r = +0{\cdot}839$, $P < 0{\cdot}001$) was found between tree weight and the amount of bridging which had occurred. Trees containing the most nearly complete rings of Hale's tissue were also the smallest. One may therefore conclude that some incompatibility effect was exerted by the Hale's rings.

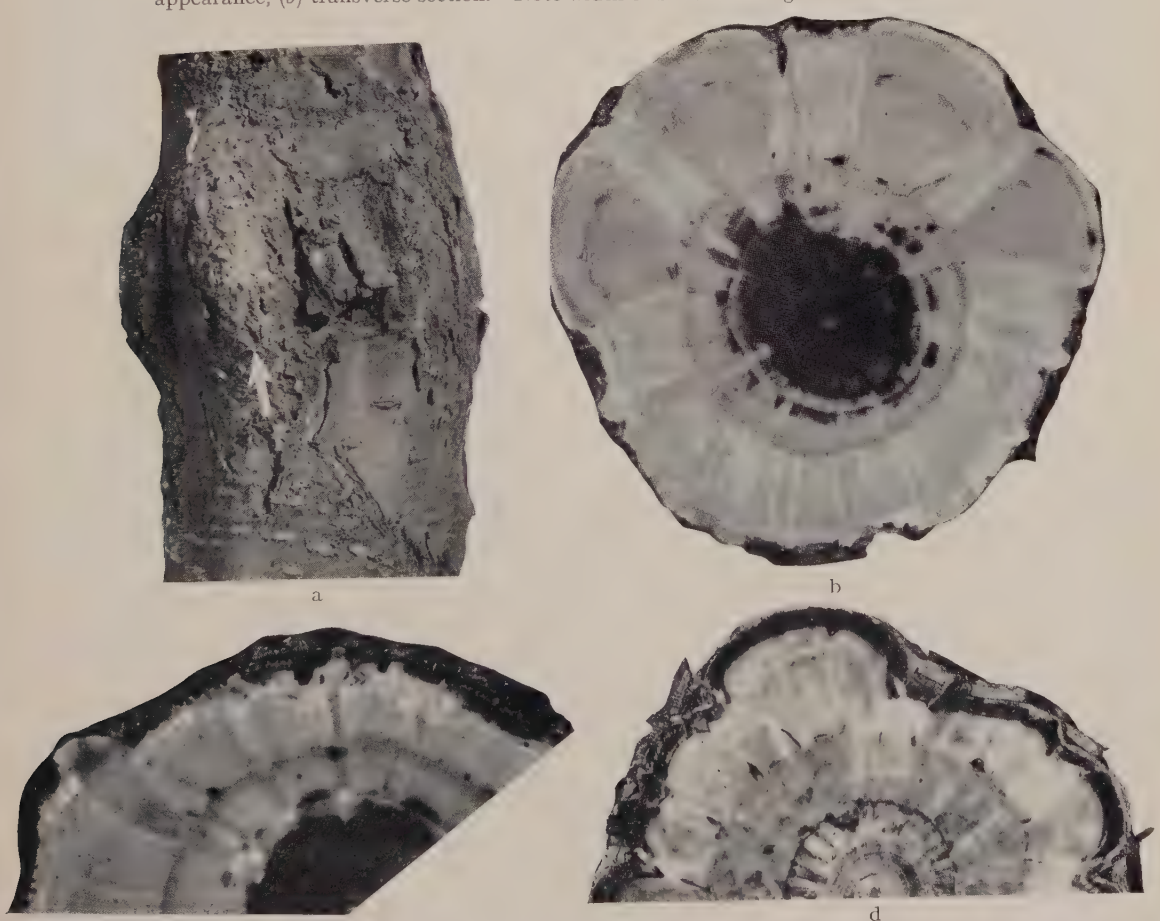
Although none of the Myrobalan B scions bore any fruit there was evidence that, both in 1957 and in 1958, trees with Hale's ring-grafts blossomed more heavily than those in the other two treatments.

PLATE I.



a b

Fig. 2. Myrobalan B ring-graft in the rootstock stem of Hale's Early/Brompton, showing : (*a*) external appearance, (*b*) transverse section. Note width of bark and irregular outline of the cambium.



a b c d

Fig. 3. Hale's Early ring-graft in the rootstock stem of Myrobalan B/Brompton, showing : (*a*) external appearance, (*b*)-(*d*) transverse sections. Vigorous Brompton bridges are marked by arrow in (*a*) and appear as darker sectors in (*b*). Bark necrosis is shown in (*c*) and parenchyma tissue and bark involution between Hale's Early and Brompton sectors in (*d*).

[*face p. 278*

FIG. 4.
Structure of union between Hale's Early and Brompton in tree of Myrobalan B/Brompton (ring-grafted with Hale's Early). Note discontinuity between vascular tissue of Brompton (above) and Hale's Early (below) and horizontal vessels above the union.

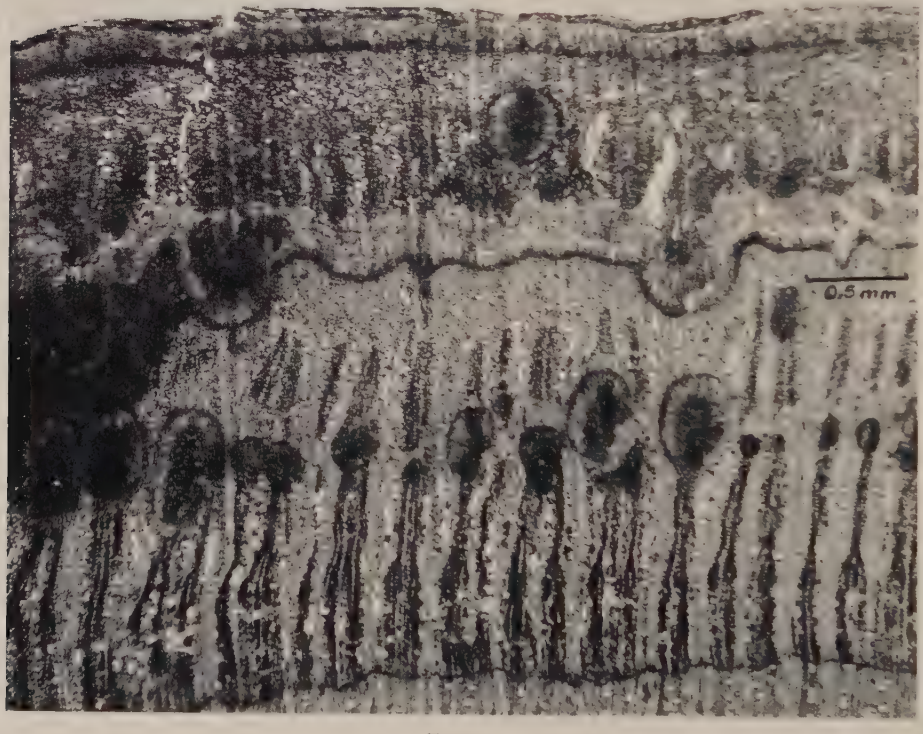


FIG. 5.
T.S. bark of Hale's Early ring-graft showing the regular onset of phloem necrosis and phellogen formation in separate parts of the peach phloem at similar stages of development.

Anatomical structure of unions and ring-grafts.

Unions were of two kinds : (1) bud unions between the rootstock and the scion, (2) graft unions between the rootstock and the ring- or patch-graft. In addition to horizontally orientated unions at the top and bottom edges of the ring, others developed in a vertical direction between rootstock bridges and ring-graft sectors.

All bud unions were good, and there was no suggestion that their compatibility had in any way been affected by the ring-grafts below them.

Ring-grafts of Brompton in Brompton stems (control trees) were perfect and in many instances could only be located by a slight depression in the external bark surface. Brompton rings from an incompatible source were rougher in external appearance, and one out of five had the abnormally wide bark and waviness of cambial outline which are regarded as non-specific symptoms of ill-health in plums.

Myrobalan B ring-grafts tended to have a rough bark and many had the swollen external appearance shown in Fig. 2a. In cross section the abnormally thick bark and uneven outline of the cambium which are shown in Fig. 2b were highly characteristic. The wide bark was associated with extensive hyperplasia in the phloem and an abnormal condition of the nuclei in many recently formed phloem ray cells. Instead of being rounded, such nuclei were much elongated with tapering ends and exhibited a strong affinity for safranin. Apart from these anatomical disturbances in the Myrobalan B bark there was no indication that unions between the ring-grafts and the rootstock had become incompatible. The extent of bridging varied. Out of fifteen ring-grafts four had remained complete, eight were less than one quarter bridged, and in three trees Brompton bridges occupied about half the cross-sectional area. There was no correlation with final tree weight. The extensive bridging of all the patch-grafts without buds and the almost complete absence of bridges in those with buds has already been referred to. While the cause of this may lie in the presence of a dormant bud it is also possible that the bark patches with buds were taken from somewhat younger branches. Unfortunately this cannot now be checked.

The external appearance of a typical ring-graft of Hale's Early with a vigorously growing Brompton bridge is illustrated in Fig. 3a. More complete rings developed into deeply fissured sunken areas from which dead patches of the outer bark were being shed. Fig. 3b shows the cross-sectional appearance of an extensively bridged ring-graft. Apart from extensive necrosis in the peach bark (Fig. 3c), a typical incompatibility reaction developed at the union of the normally compatible Hale's and Brompton tissues. This was expressed in the deep bark involutions and typical layers of parenchyma cells that developed both radially between Hale's and Brompton stem sectors (Figs. 3b and d) and horizontally at the top and bottom edges of the ring-graft (Fig. 4). This illustration also shows the horizontal orientation of some vascular tissue at the union. Necrosis in the Hale's bark affected both cortical and phloem cells. It followed the usual pattern, starting with the death of isolated cell groups, followed by the development of active cork cambia around necrotic areas, the coalescence of such cambia, and the eventual death of patches of the outer bark cut off by continuous layers of cork cells.

Fig. 5 illustrates a frequently observed pattern in the onset of phloem necrosis in this material. Death of cells starts inter-radially in tissue containing sieve tubes at a stage of development where differentiation of phloem fibres would normally begin. This observation is of interest in connection with the theory (Buchloh, 1958) that the anatomical results of incompatibility are due to the inhibition of lignification

resulting from interactions between the enzyme systems of incompatible graft components.

DISCUSSION.

Symptoms of incompatibility between Hale's Early peach and Myrobalan B are severe, develop quickly and usually lead to an early death of the tree (Garner and Hammond, 1938 ; Herrero, 1951). The combination Hale's Early/Brompton is compatible (Witt and Garner, 1931), but insertion of a Myrobalan B bark ring in the rootstock stem decreased scion growth by one third, led to excessive die-back and induced other symptoms of ill-health in the five-year old scions. Although the ring-grafts with wide irregular bark were clearly abnormal the anatomical structure of the graft unions was not affected. Inserting ring-grafts of Hale's Early into the rootstock stem of Myrobalan B on Brompton led to some decrease in scion growth where rings had not become extensively bridged, and tended to increase blossoming. It led to severe necrosis in the peach bark and induced a typical incompatibility reaction in the structure of unions between the peach tissue and tissue of the normally compatible rootstock Brompton. Deep involution of the bark and the cambial zone, the formation of undifferentiated parenchymatous tissue between the vascular cylinders, and abrupt changes in vascular orientation occurred.

These results confirm earlier observations (Herrero, 1955 ; Mosse, 1955), and establish that some principle causing symptoms characteristic of incompatibility between Hale's Early peach and Myrobalan B can be translocated across a mutually compatible stem piece. The severity of symptoms was reduced by the presence of the intermediate. Anatomical abnormalities were confined to the ring-grafts and did not extend to the bud unions or the scions four inches above them, and this suggests some polarity in the movement of factors causing structural abnormalities. There were also, however, effects on growth and cropping of the scion, and these were translocated upwards. When Hale's/Brompton was ring-grafted with Myrobalan B, growth deteriorated without accompanying defects in union structure. The adverse effects on scion growth were not reduced by the establishment of normal, vigorously growing bridges across the ring-graft. This suggests that the deterioration in growth of the peach scions was not primarily caused by difficulties in translocation, and agrees with Herrero's (1951) tentative conclusions. The possibility that the translocated factor affecting scion growth may be a virus deserves further attention.

The different behaviour of patch-grafts with and without a bud is not easy to interpret. The crop increase caused by the latter treatment could be connected with the absence of the dormant bud, or more probably with the extensive bridging of the patch which provided a large surface of contact between rootstock and ring-graft tissue. On this basis incompatibility effects on growth and cropping of peach scions could be related to the diffusion of a causal factor from cells of the ring-graft tissue.

The results of this trial indicate that Hale's Early is more sensitive to incompatibility than Myrobalan B, since both its growth as a scion and its anatomical structure as a ring-graft were more severely affected. Gur's (1957) observations, which link incompatibility reactions with the poisoning effect of cyanide liberated by the breakdown of cyanophoric glycosides, may be relevant in this connection, since such substances are more prevalent in peaches than in plums.

SUMMARY.

Evidence is presented that factors causing incompatibility between the peach variety Hale's Early and the rootstock Myrobalan B can be translocated in ring-grafted trees across a four-inch intermediate stem piece of the mutually compatible rootstock Brompton.

The variety Hale's Early proved to be more sensitive to incompatibility than Myrobalan B and was more severely affected both in its growth when used as a scion and in its anatomical structure when used as a ring-graft.

Translocation of factors causing anatomical abnormalities was confined to downwards movement, but effects on growth and cropping were transmitted to the scion. It is considered improbable that effects on growth were entirely the result of impeded translocation across the ring-grafts.

Although there was clear evidence of translocation of factors causing incompatibility, the available material was insufficient to demonstrate transmission and the question remains open whether this type of incompatibility may be caused by virus infection.

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EMPRESS MANDARIN AS A ROOTSTOCK FOR CITRUS

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COMPREHENSIVE citrus rootstock investigations began in South Africa in 1930, for it was realized that the use of rough lemon for all varieties on all soil types and in all the seven citrus-growing areas was not sound citricultural practice. One of the many rootstocks used in the trials was Empress mandarin (a selection of *Citrus reticulata* Blanco). Its potentialities as a rootstock for commercial plantings of midseason oranges were first mentioned by Marloth (1954).

The varietal name and description of the Empress mandarin do not seem to occur in the citrus literature, though it has been known for the past fifty years in the eastern Transvaal. As far as can be determined, it is synonymous with Emperor mandarin and probably originated as an importation from Australia or the Far East. Many varieties very similar to the Australian Emperor variety are known to occur, e.g., in Java and in South Africa, and Webber and Batchelor (1943) report that the Oneco mandarin, which originated in Florida, is also very similar to the Emperor. The main common characteristic of all these varieties is that the tree has numerous fine branches and tends to vigorous upright bushiness, while the fruits are loose-skinned, yellow to light orange in colour, and medium to large in size.

Apart from the increasing use of Cleopatra mandarin as a rootstock for tangerines and tangelos in California and Florida, mandarin and tangerine selections, including Oneco, have not generally found favour, though Batchelor and Webber (1948) and Akenhead (1958) have reported experiments, in U.S.A. and Nigeria respectively, on the use of various mandarin and tangerine selections as citrus rootstocks.

Empress mandarin has been used as a rootstock for tangerines and mandarins at Nelspruit since 1933, but the first comparative trials were planted in 1939 and others have been laid down subsequently. This paper reports observations and the results of trials of Empress mandarin which have accumulated over the past twenty years.

Materials and methods.

In 1939 a number of replicated trials were established in the eastern Transvaal; Empress mandarin was included as a rootstock for Lisbon lemons on sandy soil at Boulders, for Marsh grapefruit on medium clay loam alluvial soil at Malelane, and for Tomango mid-season oranges on sandy loam at Nelspruit. In 1944 rootstock trials of the varieties Valencia orange and Washington Navel orange were established on red clay loam soil at the Alkmaar Substation. Further comparative trials in which Empress mandarin was used as a rootstock were made in 1954 and 1956. Empress mandarin is included in replanting projects on old citrus orchard sites of two soil types, and it is also being used as a rootstock in variety

trials being established in the western Transvaal and at the Addo Citrus Research Station in the Eastern Cape.

In a trial started in 1957 at Nelspruit, Empress mandarin is being tested as a rootstock in comparison with 48 other *C. reticulata* varieties and hybrids, and with sweet orange and rough lemon as " controls ". In this planting both the Greathead strain of Washington Navel, known to carry both the exocortis and xyloporosis viruses, and the Palmer navel, a nucellar line free of bud-transmitted viruses, are scions. Both are known to be field-infected with the tristeza virus which is ubiquitous in South Africa.

The propagation of the trees used in the comparative plantings, the lay-out of the trials, the methods of obtaining the yield data, and the sampling procedure for the fruit quality tests were all done in accordance with the principles and technique of rootstock research as discussed by Marloth (1959).

RESULTS.

The observations and experimental results reported in this paper are derived from a number of separate trials which have all included a wide range of rootstocks. The results with Empress mandarin have been singled out from the rest, but these are compared throughout with the results obtained with the widely used rough lemon and sweet orange.

In addition to statistical data on yield and fruit quality, observations on disease resistance, polyembryony, and tree growth are also included as they are equally important characters in the selection of a rootstock.

Disease resistance.

The emphasis in selecting for disease resistance in rootstocks for citrus has changed in recent years.

Formerly, resistance to gumming diseases and root rot was sought and such resistance is still regarded as highly desirable, although with improved cultural and irrigation practices the severe deleterious effects of these disorders can to a great extent be avoided. To-day it is resistance to or tolerance of virus diseases, especially tristeza, that is the first requirement of a suitable rootstock.

No experimental evidence is available on the extent to which Empress mandarin rootstocks are resistant to gummoses. Very little information on these diseases of mandarins can be found in the literature, though Batchelor and Bitters (1952) report that the Cleopatra mandarin is more resistant to gumming diseases than the rough lemon or sweet orange. Very old seedling trees of tangerines closely similar to the Empress mandarin are known in South Africa, e.g., the de Wildt which is over 80 years old, but nothing is known as to the susceptibility of these to gumming diseases. Until results from comparative tests now under way are available, it is assumed that the Empress mandarin is relatively resistant to the fungal gummoses.

The oldest available orange trees on Empress mandarin are of Shamouti orange, now 22 years old. No sign of decline can be seen, and therefore it can be safely stated that the Empress mandarin is highly tolerant to the tristeza virus, because by their failure on a sweet lime rootstock, and by the development of characteristic pitting, the scion material of Shamouti, Valencia, Tomango, and the Greathead strain of Washington Navel oranges used in the plantings reported here was shown

to be carrying both tristeza and xyloporosis viruses. Similarly it can be stated that, since trees of all these scion lines on Empress mandarin rootstock showed no retardation in growth or any decline at a minimum age of fourteen years, this rootstock is highly resistant or tolerant to the xyloporosis virus.

The presence of scaly-butt at the union, and the retarded growth and subsequent decline of trees of the aforementioned varieties on *trifoliata* rootstock indicate the presence of the exocortis virus in this scion material. The fact that trees of all these scion lines on Empress mandarin rootstock are amongst the largest in the trials, and that they have normal smooth unions, shows that the strain of Empress mandarin used is extremely tolerant or resistant to the exocortis virus.

The Empress mandarin in South Africa, and particularly in the eastern Transvaal, is subject to the " greening " malady so pronounced with *C. reticulata* varieties and their hybrids. Greening on sweet orange is described by Oberholzer and Hofmeyr (1955), who believed it to be probably of a virus nature. Many years of observational evidence have led the present authors to ascribe these symptoms in the mandarin group to a vector-transmissible virus or virus-complex distinct from those known at present. It must be recorded that, in two batches of trees in the variety-rootstock trial (the first already 24 years old), trees of Empress mandarin on *trifoliata* show a dwarfing effect and are in an advanced stage of decline, while trees of Empress mandarin on both Empress mandarin and de Wildt naartje are large, vigorous, and in good health, although bearing " greened " fruit. In view of the extensive observational evidence available, the authors do not accept the reaction on *trifoliata* as due to exocortis, but believe it to be associated with the " greening " disease.

Nucellar embryony.

Webber (1932) showed that one of the major considerations in the selection of a citrus rootstock is the degree of nucellar embryony which it exhibits. The more highly polyembryonic varieties which produce a large number of apogamic seedlings, almost uniform genetically and of the same genotype as the mother, should be preferred. Torres (1936) found that 15 different varieties of *C. nobilis* (*C. reticulata*) exhibited great variation in their embryo counts, and Batchelor and Webber (1948) reported that various workers found that the sweet orange group gives 40–95% nucellar seedlings, the rough lemon 90–100%, and the mandarin group 80–100%.

K. E. J. Davie, geneticist at the Nelspruit Station, has studied the degree of nucellar embryony exhibited by the Empress mandarin from different sources. He found that the average number of large and small embryos per seed (not including an average per seed of 10·5 minute rudimentary embryos) was 2·7. Thus the Empress mandarin seems consistently to produce nucellar embryos and is suitable in this respect for rootstock purposes. The number of seeds per fruit varied from 6 to 24, with an average of 14.

Growth.

A characteristic of the Empress mandarin is the production of abundant fibrous roots, even in sandy soil. Nursery trees on sweet orange are inclined to be poor in fibrous root production on the lighter soils, although satisfactory on heavier soils. The presence of sufficient fibrous roots results in a more satisfactory " take " of the budlings on planting out.

Budlings on Empress mandarin rootstock are less vigorous and take somewhat longer to come into bearing than those on rough lemon, but not longer than on sweet orange. An important advantage over sweet orange rootstocks is the upright habit, without excessive side branching, of the Empress mandarin seedling. This facilitates high budding.

As far as growth of trees after planting out is concerned, Marloth (1956) reported that on sandy soil lemon trees on Empress mandarin rootstock declined at fourteen years, but not more so than the larger trees on sweet orange and rough lemon rootstocks. However, he found (1957) that on sandy loam soil, while Tomango orange trees on rough lemon initially grew more vigorously than those on Empress mandarin, from ten years onwards they began to lag behind, and at seventeen years trees on Empress mandarin were the largest. With Marsh grapefruit as a scion on heavy alluvial soil he found (1958) that at seventeen years from planting, with no difference in size, trees on Empress mandarin declined as much as those on sweet orange, but less than trees on rough lemon, and all trees showed severe sypmtoms of stem-pitting.

At Nelspruit, trees of the following scion varieties—Shamouti orange, Valencia orange, Empress mandarin, Clementine orange, Algerian tangerine, Owari Satsuma orange, Minneola tangelo—were as large and as healthy, at fourteen to nineteen years of age, on Empress mandarin rootstock as on rough lemon or sweet orange.

At Alkmaar there was no statistical difference in the stem diameter of budlings on the two rootstocks (rough lemon and Empress mandarin) when they were planted in the Valencia orange and the Washington Navel orange rootstock trials, but the trees on the former (i.e. rough lemon) grew more vigorously during the first years after planting. Fourteen years later there was no apparent difference in tree size in the navels, while with Valencia trees those on Empress mandarin rootstock were amongst the largest in the orchard and equal to those on sweet orange ; both were slightly larger than those on rough lemon rootstocks.

Yield.

The influence of Empress mandarin rootstock on the yield of fruit follows closely its performance as regards growth. Data on the yield of trees in these experiments, and the statistical significance of differences in performance, are presented in Tables I to III. Data from different plantings cover different periods. Thus with Tomango orange, twelve years of actual cropping are recorded ; with Washington Navel, the records are for fifteen years from planting, and for Valencia orange, eighteen from planting. To reflect possible relative differences in yield performance at different ages of the trees, the yearly data are grouped into three periods : the first three to five years of bearing, a middle period of four to five years, and the last three to five year period of trees in full production.

Weight of fruit per tree. It has previously been noted (Marloth, 1958) that, during the early years of bearing, Marsh grapefruit trees on rough lemon and mandarin rootstocks out-yielded trees on sweet orange, there being no significant difference eight years from planting in yield from trees on rough lemon and mandarin rootstocks. With Tomango orange (Table I) and Washington Navel orange (Table II), trees on rough lemon out-yielded trees on both sweet orange and mandarin during the early years of bearing, but at twelve years from planting there was no appreciable difference. The only difference in yield shown by Valencias planted on

TABLE I.

Yield and fruit quality of Tomango orange at Nelspruit; planted 1939 in two-tree plots with four replications.

Stock	Av. wt. (lb.) of fruit per tree per year during				Av. wt. (lb.) per fruit 1944-58	Fruit quality*				
	1944-46 3 years	1951-54 4 years	1955-59 5 years	Av. of 12 years		Rind thickness mm.	Juice %	Total soluble solids %	Acid %	Ratio T.S.S./ acid
Empress mandarin (EM) ..	55	364	469	330	0·36	5·0	52·7	10·95	1·32	8·3 : 1
Sweet orange (SO), mean of three varieties	41	328	412	291	0·34	5·1	51·3	11·2	1·37	8·2 : 1
Rough lemon (RL), mean of two varieties	84	328	312	260	0·37	5·4	51·0	10·6	1·26	8·4 : 1
Sig. diff. for group comparisons at P=0·01	RL>SO and EM	n.s.	EM and SO>RL	EM>RL	RL† and EM>SO	RL>EM and SO	EM>SO and RL	EM† and SO>RL	EM† and SO>RL; SO>EM†	RL>SO

* Average for six years during 1950-58; tested mid-June. n.s., no significant difference. † P=0·05.

TABLE II.

Yield and fruit quality of Washington Navel orange at Alkmaar; planted 1944 in two-tree plots with three replications.

Stock	Av. wt. (lb.) of fruit per tree per year during				Av. wt. (lb.) per fruit 1947-58	Fruit quality*				
	1947-50 4 years	1951-54 4 years	1956-59 4 years	Av. of 12 years		Rind thickness mm.	Juice %	Total soluble solids %	Acid %	Ratio T.S.S./ acid
Empress mandarin (EM) ..	57	175	207	146	0·50	4·8	48·9	10·0	0·93	10·8 : 1
Sweet orange (SO), mean of three varieties	57	202	202	154	0·50	5·0	49·7	10·2	0·93	11·0 : 1
Rough lemon (RL), mean of two varieties	83	196	215	165	0·44	5·3	48·0	9·5	0·83	11·5 : 1
Sig. diff. for group comparisons at P=0·01	RL>EM and SO	RL† and SO>EM	n.s.	n.s.	n.s.	RL>EM and SO	SO>RL	EM† and SO>RL	EM and SO>RL	RL†>EM and SO

* Average for six years during 1948-58; tested end of May. n.s., no significant difference. † P=0·05.

TABLE III.

Yield and fruit quality of Valencia orange at Alkmaar; planted 1940 in two-tree plots with four replications.

Stock	Av. wt. (lb.) of fruit per tree per year during				Av. wt. (lb.) per fruit 1946-58	Fruit quality*				
	1945-49 5 years	1950-54 5 years	1956-58 3 years	Av. of 13 years		Rind thickness mm.	Juice %	Total soluble solids %	Acid %	Ratio T.S.S./ acid
Empress mandarin (EM) ..	81	217	414	210	0·36	5·1	52·3	10·3	1·20	8·6 : 1
Sweet orange (SO) mean of five varieties	83	221	398	209	0·38	5·2	52·8	10·3	1·26	8·2 : 1
Rough lemon (RL), mean of four varieties	109	222	374	215	0·37	5·4	52·0	9·9	1·19	8·2 : 1
Sig. diff. for group comparisons at P=0·01	RL>EM†	n.s.	n.s.	n.s.	n.s.	RL>SO >EM	SO>RL†	EM and SO>RL	SO>RL and EM	EM>SO† and RL

* Average for six years during 1946-58. n.s., no significant difference. † P=0·05.

the three rootstocks at Alkmaar (Table III) was that trees on rough lemon slightly out-yielded trees on mandarin during the early years of bearing. It is of particular interest to note that the yield of twenty-year-old Tomango orange trees on both mandarin and sweet orange rootstocks was significantly greater than that from trees on rough lemon. Further, an average yearly yield of 330 lb. of fruit per tree for trees on Empress mandarin was significantly greater than the 260 lb. produced by trees on rough lemon.

Fruit size. Although there was no significant difference in average weight per fruit over some twelve years from trees on rough lemon, sweet orange, and mandarin rootstocks of Washington Navel and Valencia oranges, fruits from Tomango orange on rough lemon and mandarin were significantly heavier than those from trees on sweet orange. It should be noted that, as there was no significant difference in yield between trees on mandarin and sweet orange, this difference in average weight per fruit is regarded as a direct rootstock effect.

Fruit from the Valencia planting was graded during 1958 for actual size, but no significant difference as between the three rootstocks could be recorded. As the yield of trees on Empress mandarin was significantly more than that from trees on rough lemon in that year, it would be expected that fruit from trees on mandarin would on the average be smaller than from trees on rough lemon, as it is well known that in general a larger crop on a given-sized tree results in smaller fruit. This, however, was not reflected in the data.

Fruit quality.

The influence of rootstock on fruit quality under South African conditions has been demonstrated by Marloth (1949, 1956, 1957, 1958). In the last two papers preliminary evidence was offered that, in general, fruit from trees on Empress mandarin was of the same quality as that from trees on sweet orange. The data on quality of fruit produced by trees in the four rootstock trials are included in Tables I to III.

Rind thickness. The rind of fruit from trees on rough lemon was consistently thicker than that of fruit from trees on either sweet orange or mandarin. Only in the older Valencias was there a significant difference in rind thickness of fruit from trees on sweet orange and mandarin ; the fruit from trees on Empress mandarin had thinner rinds than those from trees on sweet orange.

Juice. Tomango orange fruit from trees on mandarin rootstock contained significantly more juice than fruit from trees on rough lemon and sweet orange (Table I). Valencia and Washington Navel oranges from trees on rough lemon had significantly less juice than fruit from trees on sweet orange rootstocks ; the juice content of fruit from trees on mandarin was intermediate. No consistent effect of rootstock on juice content of the fruit has been found.

Total soluble solids. Fruit from trees on rough lemon rootstocks consistently contained less total soluble solids in the juice than fruit from trees on sweet orange, and less than fruit from Valencia trees on mandarin, the differences being highly significant. It also contained less soluble solids than fruit from Tomango and Washington Navel orange trees on mandarin, but here the differences were significant only at the 5% level. Differences between fruit from trees on mandarin and sweet orange rootstocks were not significant.

Acid. The juice of fruit from trees on sweet orange rootstocks consistently had

significantly more acid than fruit from trees on rough lemon. Tomango and Valencia oranges from trees on sweet orange rootstock also contained more acid than fruit from trees on mandarin, the difference of 0·06% being highly significant in Valencia. Tomango and Washington Navel oranges from trees on mandarin contained significantly more acid than fruit from trees on rough lemon rootstock.

Total soluble solids/acid ratio. No consistent pattern for this ratio resulted from the four plantings, either during individual years of fruit quality testing or in the averaged data presented in the accompanying Tables. The T.S.S./acid ratio in the juice of fruit from Tomango and Washington Navel oranges on rough lemon was significantly higher than that of fruit from trees on sweet orange rootstocks. In Washington Navel this value was also higher than that for fruit from trees on mandarin rootstock. However, at the date of testing, the later-maturing Valencia orange on mandarin rootstock gave a ratio significantly greater than that of fruit from trees on both sweet orange and rough lemon. This is because fruit from trees on mandarin had relatively higher total soluble solids and lower acid content when compared with fruit from trees on rough lemon and sweet orange rootstocks respectively.

DISCUSSION.

The consistent performance of Empress mandarin as a rootstock fully justifies the recommendation of this variety as a rootstock for orange varieties in commercial plantings. Such factors as scion variety, area, and soil type, however, have still to be considered in greater detail.

The yield pattern of trees on Empress mandarin, with the data so far available, is not consistent and does not conform with that of trees on rough lemon or sweet orange. Young trees on rough lemon out-yield those on mandarin, but when the trees are in full bearing those on mandarin usually carry bigger crops.

The question has arisen whether any variety or strain of loose-skin mandarin will be as good a stock as the particular Empress mandarin used in this work. The differences in the performance of various *C. reticulata* varieties force the authors to advise caution with regard to the source of seed when mandarin is used as a rootstock. However, the comprehensive rootstock trial recently set out, including many loose-skin mandarin varieties and strains, should assist in answering this question. To date, only Empress mandarin can be specifically recommended.

For South African export marketing reasons, it is desirable that the late-maturing Valencia oranges reach the minimum maturity requirements in respect of fruit quality, as laid down by government export regulations, as early in the season as possible, thereby avoiding competition with early fruit from northern hemisphere countries. Thus, while sweet orange rootstock results in an overall increase in fruit quality, with more juice, higher total soluble solids, and more acid, the *ratio* of T.S.S. to acid is the same as in fruit from trees on rough lemon rootstocks. However, with fruit from the Alkmaar Valencia planting, tested over six years, there was no significant difference in acid in the juice from fruit of trees on mandarin and rough lemon rootstock, but significantly higher T.S.S. in the former. Thus, fruit from trees on mandarin has a significantly higher ratio than fruit from trees on both sweet orange and rough lemon rootstocks.

It is not recommended at this stage that Empress mandarin should necessarily replace either rough lemon or sweet orange as a rootstock for commercial use in

South Africa. The present work shows that trees budded on mandarin produce a high yield as well as fruit of the best quality. The longevity of trees budded on mandarin is still to be determined, but there are indications that it will be greater than that of trees on rough lemon and at least equal to that of trees on sweet orange rootstocks.

SUMMARY.

Comprehensive citrus rootstock investigations in South Africa have included the Empress mandarin which appears to resist or tolerate the tristeza, exocortis, and xyloporosis viruses.

Seed of Empress mandarin was found to be consistently polyembryonic, and thus suitable in this respect for use as a rootstock.

In the nursery Empress mandarin has proved itself suitable for propagation purposes, producing abundant fibrous roots, even in sandy soil. Although during early years of growth, especially on sandy soil, trees on rough lemon outgrew those on mandarin, from around ten years of age trees on mandarin forged ahead and at twenty years were equal to those on sweet orange, both of these being larger than trees on rough lemon rootstocks.

Observations over a period of twenty years have shown that, when first coming into bearing, trees of Washington Navel, Valencia and Tomango orange on rough lemon stocks tended to out-yield those on mandarin, but this difference soon disappeared and with Tomango orange was reversed.

Fruit from trees on mandarin was of high quality. The rind was thinner than in fruit from trees on rough lemon, and the juice had a higher total soluble solids content with all varieties. Fruit from Tomango and Valencia orange trees on sweet orange contained more acid than fruit from trees on mandarin rootstock. With the late-maturing Valencia orange, fruit from trees on mandarin had a higher total soluble solids/acid ratio than that from trees on rough lemon and sweet orange rootstocks.

The use of Empress mandarin as a rootstock for oranges in commercial plantings is recommended, especially on sandy soils, or when the scion material is suspected of carrying bud-transmissible viruses, or in countries where tristeza is active.

ACKNOWLEDGMENT.

The authors wish to acknowledge with appreciation the valued assistance of Mr. K. A. W. Helff, Biometrician at the Nelspruit Station, in undertaking detailed analysis of all available data, only the summary of which is presented in the accompanying Tables.

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BOOK REVIEWS

TOMATOES—CULTIVATION, DISEASES AND PESTS. Ministry of Agriculture Bulletin No. 77, 5th Edition. (London : H.M. Stationery Office. 1959. Pp. 74, illus. Price 5s. 6d., 5s. 11d. post free.)

My first reaction on reading the latest Ministry information on tomato growing was to consider the policy behind the publication of the Bulletin. Is it for (*a*) general information describing present practice, technical problems and possible developments, (*b*) students or apprentices looking for authoritative condensed information for examination purposes, (*c*) the grower, who is earning his living either as a worker or occupier of a holding and who wishes to improve his practice, techniques, equipment or facilities?

My personal impression is that, whatever the target, the chief use will be by students. For examination purposes the bulletins are considered to give the official point of view and, because they are cheap, most students acquire a collection covering their interests. In growers' activities it is quite unusual to have them quoted or to see up-to-date copies on the bookshelves in their offices or conveniently to hand.

Consideration of the purpose of Bulletin 77 is particularly important at the present time. The tomato industry believes its economic position to be perilous. Costs of labour and materials have risen while selling prices have in the last three years dropped dramatically. As an example of the increasing economic pressure the following tonnages of tomatoes were required per acre at Fernhurst to cover all costs : in 1957, 51 tons ; in 1958, 57 tons ; in 1959, 66 tons.

Marketing arrangements remain unhappy. Undoubtedly the industry must improve the quality of tomatoes and perhaps aim at greater uniformity of fruit shape and size, but this cannot be easily achieved with existing varieties without financial risks.

Government assistance to horticulture within the agricultural sphere continues to be in the form of grants for improvement, research, advice, and technical service. Growers must be encouraged to make the fullest use of these aids and to seek positive guidance on how to improve the general level of efficiency so as to compete with the more uniform conditions and better organized and more positively directed production of the Netherlands.

Growers themselves take an increasing interest in how the money spent on their behalf is used ; first by making certain that their problems are known both to advisers and experimental and research workers. They then look for an adequate balance of applied and fundamental research into their problems.

I believe this preamble to be of considerable importance in the case of tomatoes. If one looks critically at Bulletin 77 as a grower seeking guidance on how to grow a particular type of crop one finds a review generalizing on many points. Such generalizations are admirable for teaching principles but do not always follow in practice and certainly could not be authenticated.

In the section on top dressing, feeding and crop management there is certainly good reason to avoid dogmatism. Many of the statements reflect lack of knowledge and the need for more research into the environmental requirements of tomatoes.

This, however, does not help the grower and I believe it is the duty of those with specialist knowledge to be more specific in their interpretation for the practical man. One useful example of this is the table guide to water requirement.

If the main purpose of Bulletins is to aid the grower I am sure he would appreciate a streamlining of approach. This could include a statement of the problems, positive recommendations, and a review of developments with suggestions as to how they may be applied.

G.D.L.

DIE ERNÄHRUNG IM BLUMEN- UND ZIERPFLANZENBAU. By Franz Penningsfeld. (Hamburg and Berlin : Paul Parey. 1960. Pp. 217, illus. Price 38 DM.)

The methods employed by the author and his staff to study the nutritional needs of ornamental plants are described in the first part of this book. Using rooting media ranging from sand to peat or normal potting compost, the plants were grown with nutrients which covered a range of concentrations and proportions of nitrogen, phosphorus and potash, and sometimes magnesium, iron and the trace elements.

In the second part the results are described in detail for each of 37 plants of importance in commercial horticulture. Over 90 tables give the weights and chemical composition of the plants under the different treatments. Conclusions are set out as to the optimum levels of supply of the major elements and in some ininstances consideration is also given to such things as trace elements, light, temperature, water supply and toxicities.

Finally there are general conclusions and some mammoth tables which repeat the chemical data in Part II.

The publishers claim that this book will be equally valuable to research institutes, advisory officers, managers, scientifically-minded horticultural students and the practical man. In the face of the language barrier it would be a brave man who would embark on this mass of information (217 pages). But there is much of value to be found in the 63 black and white and 64 coloured photographs. It is to be hoped that a condensed but fully illustrated version may one day appear in English.

A.V.D.

MIST PROPAGATION OF CUTTINGS. By Patricia Rowe-Dutton. (Commonwealth Agricultural Bureaux, Farnham Royal. 1959. Digest No. 2. Pp. 135, illus. Price 10s.)

Here is a well ordered summary of a vast and scattered literature for propagators wishing to install a modicum of automation. There is no need for the practical man to search further but, should he feel so inclined, the 100 recent references should prove a sufficient deterrent.

The essential difference between humidification and mist is clearly explained. Humidification reduces transpiration by wetting the air whereas mist maintains a film of water on the plant, any moistening of the air being incidental. The important difference is that mist sprays *cool* the leaves, making them cooler than the surrounding air, consequently both transpiration and respiration are greatly reduced. Only light shading is needed and food reserves are rapidly accumulated and so become available for root development.

The practical gains from mist are that soft sensitive cuttings, with the highest rooting potential, may be used ; new growths taken early have more time for growth in their first season. There is greater freedom from disease, due partly to constant washing but possibly, one imagines, just as much to cooling.

Inevitably there are troubles, excessive misting leads to leaching of nutrients from both plants and media but the major difficulty, as in all systems involving climate control, is transference or hardening—the age-old nursery problem. Rooting under mist is an easy matter ; re-establishment in a normal environment is difficult. There are many devices. Grouping the cuttings by speed of rooting simplifies procedure and the use of "weaners", i.e., control mechanisms which interfere with the mist sprays as required, are a great help. Portable apparatus enables a bed of cuttings to be rooted in soil-beds outside and overwintered *in situ*. When a large variety of subjects are propagated, nurserymen pot cuttings rooted in mist and transfer them to frames and other structures where they are hardened by well established manual methods.

The remarkable success of mist has encouraged its use for subjects which are more efficiently handled in other ways. Plants which can be readily rooted by large hardwood cuttings in open ground, or in unheated frames over winter, are best handled so, reserving the mist system for shy-rooters or for the speedy rooting of herbaceous material for glasshouse work.

Miss Rowe-Dutton has dealt with all aspects of the subject and so clarified and condensed the available information that even the horniest-handed propagator will not begrudge time spent in reading this excellent digest, nor even its price which is covered by the sale of a couple of shrubs.

R.J.G.

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HORTICULTURAL ABSTRACTS

A Quarterly Journal for the research worker and progressive grower, issued regularly since 1931 by the COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS at East Malling Research Station.

CONTENTS. A digest of world research on the problems of the fruit-, vegetable- and flower-grower, of the tobacco-producer and of the tropical and sub-tropical planter.

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